MEMORANDUM

DATE: June 1, 2019

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SUBJECT: **Incomplete and Inadequate Evaluation of Potential Catastrophic Failures for Tailings Storage and other Facilities for the Proposed Pebble Project**

Executive Summary

This memorandum describes the inadequacy of the subject evaluation provided in the Draft Environmental Impact Statement (DEIS) for the proposed Pebble Project. Potential failures of major project facilities, such as catastrophic failure of tailings storage facilities (TSFs) could result in significant, short and long-term as well as cumulative environmental impacts and potentially loss of human life. Our review and resulting comments demonstrate and conclude that the consideration and evaluation of failure modes in the DEIS fails to recognize the extreme nature of the Alaska climate and landscape, has been highly biased in favor of the proposed project, and performed to support a decision already made. Consequently, the DEIS fails to include clear acknowledgements of potential, and perhaps likely, environmental impacts and thorough investigation into the catastrophic environmental harm that would result.

In addition, as a consequence of the failure to take a hard look at the potential environmental impacts, alternatives such as downstream construction methods for TSFs or filtered tailings were eliminated from consideration as alternatives to the proposed and preferred TSF designs. Because of this inadequate evaluation, it is clear that the failure to consider potential failure modes constitutes a major and critical data gap in the DEIS for the proposed Pebble Project; therefore, the DEIS must be revised to include substantial critical information that is currently missing. The revised DEIS should then be released to cooperating agencies and the public for review and comment.

Identification and Inclusion of Critical Failure Modes

According to Section 4.27 Spill Risk of the Pebble DEIS: "*This section addresses the spill risk for the following substances: diesel fuel, natural gas, copper-gold ore concentrate, chemical reagents, bulk and pyritic tailings, and untreated contact water.*" (DEIS at 4.27-1). As this describes the

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primary potential discharges from the mine that could result in impacts to the environment as well as human health that should be evaluated by the EIS process, it is one of, it not the most, important section in the DEIS.

The mining industry, public, and regulators are well aware that TSF failures are common to mine tailings dams, with most experts agreeing that the current failure rate of two catastrophic TSF failures per year world-wide constitutes a significant risk, and that failures can occur regardless of region, jurisdiction, or adoption of best management practices. Since NEPA requires that an EIS take a "hard look" and include forthright acknowledgment of potential environmental harms, it was expected the Pebble DEIS would evaluate the potential impacts from a Bulk TSF failure. Therefore, it was surprising as well as objectionable that the DEIS did not include a bulk tailings release scenario for a catastrophic release scenario, but instead chose to limit the analysis performed to a scenario involving only a bulk tailings delivery pipeline rupture. This constitutes a fatal flaw in the current iteration of the DEIS.

As noted in the DEIS, Section 4.27.6.9 Tailings Release Scenarios, under the Bulk Tailings Delivery Pipeline Rupture scenario: "*The total volume of solid tailings released would be 0.5 million ft^3 (40,000 tons), and the total volume of contact water released would be 1.0 million ft^3.*" (DEIS at 4.27-76). This scenario significantly understates the potential for impacts as compared to a TSF failure. Given that the final capacity of the Bulk TSF for the proposed Pebble Project would be 1.1 billion tons, a catastrophic failure would potentially result in the release of hundreds of millions of tons of solid tailings together with contact water that could easily exceed 1.0 billion cubic feet (ft^3).

Background

The Pebble DEIS includes Sections 4.27.6.4 Historical Examples of Tailings Releases, 4.27.6.5 Probability of Failure, 4.27.6.6 Risk Assessment for the Proposed Embankments, 4.27.6.7 Existing Response Capacity, and 4.27.6.8 Mitigation prior to Section 4.27.6.9 Tailings Release Scenarios. According to Section 4.27.6.6 Risk Assessment for the Proposed Embankments, *"the US Army Corps of Engineers (USACE) hosted an EIS-Phase FMEA workshop to assess the likelihood of a spill and the severity of potential environmental impacts from the major proposed embankments in the bulk TSF, pyritic TSF, and main WMP. . . . For each failure mode, the expert panel rated the potential environmental impacts for their severity. The panel then identified those failure scenarios that have a relatively low probability of occurrence, and comparatively high level of consequence (AECOM 2018l). For each facility, one scenario was selected for impacts analysis in the EIS."* (DEIS at 4.27-71 to 4.27-72).The EIS references an "*EIS-Phase FMEA Report for a full discussion of* *scenario selection (AECOM 2018l)."* (DEIS at 4.27-72). According to *Section 4.27.6.9 Tailings Release Scenarios, Workshop participants reviewed the conceptual designs of the bulk and pyritic TSFs and assessed the likelihood of a release; and the severity of resulting consequences for each facility. Minor releases that would have relatively minor impacts were not selected as scenarios for analysis in the EIS, because the associated impacts would be within the range of the selected scenarios. Massive, catastrophic releases that were deemed extremely unlikely were also ruled out for analysis in the EIS."* (DEIS at 4.27-75).

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TECHNICAL REVIEW

Introduction

Following review and consideration of the DEIS rationale for the tailings release scenarios chosen, Ridolfi performed a critical review of the EIS-Phase Failure Modes and Effects Analysis (FMEA) Report (DEIS reference AECOM 2018l). This critical review, which includes technical comments on the methodology used in the EIS-Phase FMEA and a re-evaluation of the effects and likelihoods rankings and consequences severity, is provided with this memorandum as Attachment 4A.

Detailed Comments

Specific comments are included in the critical review below pertaining to the EIS-Phase FMEA Report as a basis for summarized information provided in the DEIS.

Section 4.27 Spill Risk

General

In this Section 4.27 the USACE has failed to take a hard look at the collective impacts of several, high probability spills that would occur over the life of the proposed project. The potential impacts of frequent and continuous leaks and spills from mining operations, support facilities, and equipment used in mining and transport of mining products, supplies, and materials need to be recognized, quantified, and evaluated in this DEIS.

This section separates each potential spill, release, or source of contamination into a separate and discrete theoretical event that occurs in isolation, and then assumes that the contamination naturally mitigates its effects through natural dissipation, dilution, dispersion, and biodegradation. This overly simplified and biased evaluation needs to be expanded to take a hard look at all potential spills and releases at several locations within the areas affected by the proposed project. The impacts associated with multiple spills and releases needs to be recognized and quantified. Then the potential short-term and long-term impacts of these collective spills and releases needs to objectively quantified and evaluated in this DEIS.

In addition to separating the sources of leaks and spills from one another, this section separates the natural resources affected into separate and discrete receptors. This overly simplified, narrowly focused, and limited analysis then underestimates the impacts to these natural resources and doesn't consider the broader effects on cultural resources and Alaska Native people of the region. The USACE needs to expand the evaluation of these impacts and take a hard look at the entire food chain from microinvertebrates and macroinvertebrates upward through the food chain to wildlife and humans.

Furthermore, this section does not address the collective effects of multiple spills and releases on natural resources and cultural resources on which Alaska Native people and residents of the region depend for their well established and sustainable ways of life.

USACE must address potential impacts from spills and contamination to cultural resources and subsistence in this section. USACE fails to mention cultural resources once, and the DEIS evaluation of impacts to subsistence from spills and contamination is incomplete. USACE has included spill risk assessments for cultural resources in the final EISs for the Donlin Gold Project and Point Thomson Project and should also include it for this proposed project.

In the subsections of this section addressing potential impacts to water from spills and contamination, USACE limits the analysis to the physical environment and fails to consider potential impacts to the cultural environment. While USACE does address potential impacts to subsistence, USACE casually writes off these impacts by repeating a variation of the phrase, "Quick response and cleanup, . . . testing wild foods and communicating the results to local people in a timely manner could help mitigate contamination concerns . . ." in each of the subsistence subsections in this section. (DEIS at 4.27-18, 4.27-31, 4.27-50, 4.27-56, 4.27-92, 4.27-112, 4.27-128). USACE's repetitive response grossly underestimates the potential impacts that spills and contamination could have on the Dena'ina, Yup'ik, and Alutiiq people in the proposed project area. The waters of the proposed project area are sacred. The waters of Iliamna Lake, Koktuli River, Talarik Creek, and countless other lakes and creeks serve as sources of drinking water, the basis for a traditional way of life dating back thousands of years, and religious ceremonies. The lack of sufficient evaluation of potential project impacts on Alaska Native people and their culture constitutes a significant fatal flaw in the DEIS.

In the Pebble Project Environmental Baseline Document for Bristol Bay Subsistence and Traditional Ecological Knowledge, (SRB&A 2011), residents from every community studied, reported concerns about contamination and spills. Kokhanok residents describe the potential cultural impacts from spills and contamination in Iliamna Lake this way:

> *My main concern is the water. That is what we drink from; we get our fish from there. That is one thing that I don't want ruined is the water, the freshwater. (SRB&A Kokhanok Interview May 2005)*

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> *I'm concerned about the salmon, that's our life right there. If our lake dies, I think we are all going to die. Here, we can't get any water, and that's why we have that pipe in the lake. We have too much iron in the ground water. Water is the biggest concern. And fish, but there are other areas I think it could affect: the plant life and stuff. All the water will go to all the animals and we will be affected.*
> *(SRB&A Kokhanok Interview May 2005)*

One New Stuyahok resident succinctly stated the cultural importance of the region's water this way:

> *Water gives off life to every living thing. Water is so precious. I wouldn't trade water for one [piece of] gold. Water should never be impacted.*
> *(SRB&A New Stuyahok Interview April 2005)*

In the following quote, an Igiugig resident gives voice to the potential that residents may abandon harvesting salmon, a central tenet to their culture, if there's a spill in Iliamna Lake:

> *This [the Kvichak River] is our only outlet; there's no other way to get into the lake. There's Lake Clark but it drains down into here. If something happens here [in Iliamna Lake], we will be buying salmon in a can.*
> *(SRB&A Igiugig Interview May 2005)*

The sacredness of water and salmon are interconnected. Abandoning salmon subsistence would decimate the people of the proposed project area. Buying canned salmon is not a viable replacement for harvesting your own salmon, and teaching your children how to do it, as your ancestors have done for thousands of years. Spills and contamination will have significant and irreversible cultural implications regardless of size and how quickly they're cleaned up.

Dr. Boraas and Dr. Knott further explain in the EPA's 2013 Bristol Bay watershed assessment appendix Traditional Ecological Knowledge and Characterization of the Indigenous Cultures of the Nushagak and Kvichak Watersheds, Alaska the interconnected sacredness of salmon and water to the residents of Bristol Bay this way:

> *They continue to practice a first salmon ceremony paying homage to the first salmon caught in the spring and the renewal of their cycle of life. The rivers are*

> *blessed by priests annually in the Great Blessing of the Water at Theophany, celebrating the baptism of Christ and symbolically purifying the water of contamination preparing it for the return of the salmon. This ceremony, for Orthodox Yup'ik and Dena'ina, is the pure element of God expressed as sanctified nature. The holy water of the rivers derived from this ceremony is used to bless the homes, churches, and people and is believed to have curative powers. (Pages 2-3)*

It is clear from the concerns raised by residents in interviews with SRB&A on behalf of the proposed Pebble Project for the Environmental Baseline Document for Bristol Bay Subsistence and Traditional Ecological Knowledge that residents expect the proposed project to contaminate the water. If the project is built, there will be spills and contamination; perhaps the spills will be small, perhaps they will be large. Regardless of size and how quickly the spills are cleaned up, the spills will confirm residents' concerns about contaminating the water, adding to the perception the water is unsafe because of the mine. According to Russian Orthodox clergy V. Rev. Alexi Askoak, "*human-caused pollution and other contaminants . . . are a form of sin*" (Boraas and Knott 2013:129). The concerns and perceptions of this "sin" from the proposed project are stressful and impact cultural beliefs that USACE must recognize and analyze in this section.

A complete list of hazardous materials that would be used as part of the proposed Pebble Project should be included in the DEIS, and the process used to select substances for which spill risk would be evaluated in this section should be described. The spill risks evaluated in this section should include any that may have unique impacts on elements of the environment, even if the overall magnitude of the potential risk may be lower than those currently included. A table summarizing the various hazardous substances, spill scenarios, and elements of the environment potentially affected should be included in the DEIS.

The term "mitigation" is used in different ways in DEIS that create confusion. The following paragraph is taken from EPA's website on a page titled "Section 404 of the Clean Water Act, Types of Mitigation under CWA Section 404: Avoidance, Minimization and Compensatory Mitigation":

> The White House Council on Environmental Quality (CEQ) has defined mitigation in its implementing regulations for the National Environmental Policy Act to include avoiding, minimizing, rectifying, reducing over time, and compensating for impacts. The Clean Water Act Section 404(b)(1) Guidelines, developed by EPA in coordination with the U.S. Army Corps of Engineers and issued in 1980, establish substantive

environmental criteria which must be met for activities to be permitted under Clean Water Act Section 404. The types of mitigation enumerated by CEQ are compatible with the requirements of the Guidelines; however, as a practical matter, they can be combined to form three general types of mitigation: avoidance, minimization, and compensatory mitigation.

Planning, permitting, and design of features and structures for the proposed project should be conducted in strict conformance with the definitions, regulations, and guidelines of the Clean Water Act. If the proposed project cannot demonstrate conformance and compliance with the Clean Water Act, it should not be permitted.

The descriptions and conclusions of this section indicate that stress from spills would last from 1 to 12 months, basically during the spill and during cleanup of the spill. We strongly disagree with this opinion and recognize this stress factor as an environmental justice issue with respect to the affected communities. Stress due to deep concerns about spills, releases, and contamination of natural resources is already obvious and is increasing during this permitting process. This level of stress will continue through the life of the proposed project and beyond. The communities in the areas affected by the proposed project will experience undue stress "as long as that mine is up there" or while there is any possibility of the mine being permitted and built.

An excellent example of an event that caused long-term stress among the people of Alaska is the Exxon Valdez oil spill. On March 24, 1989, the oil tanker Exxon Valdez ran aground on Bligh Reef after leaving Valdez, Alaska causing a large oil spill in Prince William Sound in the Gulf of Alaska. This major spill resulted in massive damage to the environment, including the killing of around 250,000 seabirds, nearly 3,000 sea otters, 300 harbor seals, 250 bald eagles and up to 22 killer whales. Many people observed, experienced, or were adversely affected by this catastrophic spill, and many are still experiencing that stress now, 30 years later, and many are still suffering the long-term effects.

With respect to the residents of the areas affected by the proposed project, the existence of the mine, the infrastructure, and the constant noise and traffic would contaminate the landscape from a spiritual standpoint. If permitted and constructed, the proposed project would be a blight and scar on the land that can never be fully erased. Even if a major spill or release could be prevented, most residents of the region would consider the existence of the proposed project an environmental and cultural disaster.

4.27.2 Diesel Spills

Potential impacts to air quality from diesel spills need to be quantified and evaluated in the DEIS.

Diesel spills during fuel transfer, handling, and fueling of equipment are common and frequent, and the environmental impacts over time are significant. The environmental impacts of larger spills are often severe. The USACE should provide statistics to support the claims and statements made in this section. Adverse impacts from diesel spills that occurred over 70 years ago are still being addressed and cleaned up throughout Alaska.

The scale and aerial extent of the proposed project would result in several releases of diesel in several locations throughout the watersheds of the affected areas. The collective and combined impacts of all the diesel released to the air, water, soil, and sediments need to be acknowledged, quantified, and evaluated in this EIS. The USACE needs to take a hard look at the potential impacts of spills of diesel and all other substances that will be transported, handled, and used throughout the areas affected by the proposed project.

The USACE needs to evaluate the potential short-term and long-term impacts from a vessel sinking with a load of diesel aboard.

The statement *"ULSD . . . is naturally degraded by microbes"* requires further discussion. (DEIS at 4.27-4). In general, microbial degradation is slow in colder and nutrient-limited environments. The DEIS should provide evidence that microbial degradation would occur under conditions similar to those of the affected environment surrounding the proposed Pebble Project. Similarly, the potential for evaporation may be lower in colder environments, increasing water quality impacts.

The last few sentences of the first paragraph are contradictory. The statement that diesel transportation occurs *"without incident"* is followed by acknowledgment that diesel spills occur frequently in Alaska and elsewhere, are difficult to contain, and may have impacts ranging up to severe. (DEIS at 4.27-4). The DEIS should acknowledge that diesel spills will occur on a regular basis and use historical information to estimate the frequency and magnitude of diesel spills that are foreseeable based on the quantities estimated to be transported and used as part of the proposed Pebble Project. The quantities expected to be transported and used are described in some detail, but that information is not used to estimate spill quantities in various areas of the proposed Pebble Project. Below are some of the obvious questions raised by the text that are not addressed in Section 4.27.

The DEIS should describe the secondary containment for a 1.25-million-gallon storage tank located in an area where tsunamis, earthquakes, and other large-scale threats to the integrity of these tanks could occur.

The DEIS should include information about the steel outer frames used to transport the individual ISO tanks to the proposed mine site to demonstrate that these tanks are leak-proof. The DEIS should describe the consequences, for example, if these shipping containers were to be lost in Iliamna Lake due an accident caused by adverse weather conditions or other factors.

A significant number of haul trips are proposed with just over 19,000 gallons of diesel per trip, over relatively primitive roads in adverse weather conditions. The DEIS should describe the assumptions made regarding the number of accidents that may occur per year and the potential loss of diesel per accident.

Spill response on Iliamna Lake or at the Port would be significantly hampered by high winds, choppy lake or sea conditions, ice cover outside the ferry path, and cold temperatures, particularly in winter months. Previous spills in Alaska have proven difficult to respond to due to similar conditions. The DEIS must provide a realistic assessment of the ability to effectively respond to such spills, informed by agencies responsible for assistance and response in remote areas of Alaska.

Chapter 5 does not currently contain any information about mitigation or spill response for these scenarios; however, such information should be integrated into Chapter 5. The DEIS should specifically describe how spill response would occur in challenging conditions, such as when Iliamna Lake is iced over or when there are high winds and wave heights.

4.27.2.1 Fate and Behavior of Spilled Diesel

This subsection implies that diesel, once spilled or released into the environment, naturally degrades or evaporates into the atmosphere, and therefore does not persist in the affected environment. This implication is inaccurate and misleading, since contamination from diesel spilled over 70 years ago persists throughout Alaska, and the toxic effects on the environment persist as well.

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The USACE needs to take a hard look at the potential impacts of releasing diesel vapors and vapors from other volatile substances (natural gas) into the atmosphere throughout the life of the proposed project. These and other contributions to greenhouse gas emissions need to be quantified and evaluated in the DEIS.

In the seventh paragraph is the following statement: "*A site-specific oil spill trajectory analyzing a 300,000-gallon spill during winter conditions estimates that 67 percent of the diesel would evaporate within 4 days; during spring conditions, 89 percent would evaporate within 4 days (Owl Ridge 2018).*" (DEIS at 4.27-5). This statement indicates that a relatively high volume of diesel vapors would be released to the atmosphere following a spill. The potential impacts to the atmosphere from these releases needs to be quantified and evaluated in the DEIS. The constituents that evaporate as vapor and those that remain in the soil, water, and sediments need to be identified and quantified, and the impacts to these media need to be evaluated in the DEIS.

Estimates in this section of the percentage of diesel that may evaporate are biased high by the assumptions that 1) the diesel spill is small (undefined) and 2) temperatures are above freezing. Considering the volumes of diesel expected to be transported, the DEIS should describe a more typical scenario in which a large diesel spill occurs during adverse winter weather conditions, when the ground and water may be covered with snow or ice. Even under the optimistic conditions described here, significant impacts to aquatic life would certainly occur within the early days of a spill and due to residual oil even after most of the oil may have been recovered or dispersed.

Based on experience in the field, a relatively small oil spill in a pristine area could go undiscovered for an indefinite period, and the oil could flow thousands of feet from the spill source into a wetlands and river. The responsible party could spend months and millions of dollars attempting to recover the oil and clean up the spill, and 30 years later, there would still be pockets of oil in the wetlands adjacent to the river. Some of the oil would evaporate, but most would soak into the wetlands and persist for decades.

The description of a marine spill potentially oiling a beach seems to be assuming a sandy beach. However, the rocky substrate adjacent to the proposed port site would likely be oiled differently, with oil being trapped in small gaps and interstices in the rocks. In such cases, not only may natural recovery take much longer, but spill response efforts are also hampered by the substrate.

4.27.2.2 Historical Data on Diesel Spills

The information provided in this section should be put into context by presenting it as "per-trip" or "per-volume" data, rather than an absolute number of spills or release volumes. In this way, the information could be related to the amount of traffic projected for the proposed Pebble Project and the corresponding numbers of probable large spills and small spills estimated.

Spill Frequency and Volume.

Many diesel spills are probably not reported when they occur in remote locations in the vast open areas of Alaska, especially at short-term or temporary work sites. Using information from reported spills probably leads to underestimates of the frequency, quantity, and impacts of diesel spills. The USACE should develop objective and unbiased estimates of the amount of fuel that will be spilled and the cumulative effects of multiple spills at several locations. Once the probable spill volumes and extent are determined, the USACE should take a hard look at the short-term and long-term impacts of the collective spills and releases. This thorough and complete evaluation of potential impacts should be provided in the DEIS.

Tanker Trucks

The collective quantity and potential impacts from several spills from fueling equipment and vehicles over the life of the proposed project needs to be estimated and evaluated in the DEIS.

The historical data probably understate the frequency, quantity, and impact of spills in Alaska. The unprecedented scale and aerial extent of the proposed project and remote nature of the areas affected do not lend themselves to comparison to other existing or historic projects in Alaska.

This paragraph indicates that the Applicant will haul diesel by truck with three trailers (DEIS 4.27-7), while most fuel transport in Alaska is by one or two trailers. Consequently, the potential for spills of greater quantity is higher. The potential impacts to the environment from such spills during the life of the proposed project and well into post-mining phase needs to be quantified and evaluated in the DEIS.

More information should be provided on conditions on the Dalton Highway, to better compare estimates of spills and spill recovery. For example, the DEIS should address whether trucking will occur year-round. If triple-trailer trucks are proposed, the projected volume of spills should be increased proportionately with respect to the single-trailer data.

Marine Tanker Vessels

Regarding the statement in the second paragraph: *"PLP has committed to transporting diesel in double-hulled barges."* (DEIS 4.27-7). The DEIS should address how the Applicant's commitment will be enforced. It should identify whether this commitment be included as a permit condition, or by specific regulations that require double-hulled containment of diesel. The DEIS should specify the instrument or regulations that will require double-hulled barges and other containment during transport and storage.

The DEIS should address how the Applicant has committed to using double-hulled barges. In any case where such a commitment is stated, a reference to the project application should be provided. If there is no such statement in the project application, it cannot be assumed for the purposes of the DEIS.

In the fifth and last paragraph, the following statement is found: "Based on the most recent data from BOEM for Oil-Spill Occurrence Rates for OSRA (BOEM 2016), the probability of a spill of between 42,000 and 420,000 gallons is 2.5×10^{-4} per year. This equates to an average recurrence rate of 4,000 years, or a probability of occurrence of 0.50 percent in 25 years, or 1.9 percent in 78 years (AECOM 2018n)." (DEIS 4.27-7 to 4.27-8). This calculation of probability of a large spill is of questionable validity for use in the DEIS. Considering the unprecedented scale and complexity of the proposed project, such a spill should be expected at least once during the life of the operation. Such an event should be described and quantified, and USACE should make a detailed assessment of the potential short-term and long-term impacts to water, soil, sediment, fish, wildlife, and people. A large spill event should be evaluated at several vulnerable locations within the areas affected by the proposed project, and the potential short-term and long-term impacts should be evaluated in each case.

The USACE needs to recognize, quantify, and evaluate the impacts of several, more frequent, relatively small spills and releases that would occur at fuel transfer points and fueling locations, including at various locations where mobile equipment would be fueled, throughout the life of the proposed project. The collective and cumulative impacts from all these spills needs to be recognized and evaluated in the DEIS.

Ferries

The discussion of spill risks from ferries appears to rely on information on specific vessels provided by the Applicant. An independent review of similar vessels should be conducted by the USACE and reported in the DEIS. Since the USACE has stated that Appendix K4.27 will not be forthcoming, the statistical information on the probabilities of diesel spills from ferries referenced here should be provided in the main text of this section.

4.27.2.3 Existing Response Capacity

The provisions described in this subsection are not related to existing response capacity but are proposed provisions that are apparently being offered by Pebble Limited Partnership (PLP) to mitigate spills and releases of diesel. Existing capacity, if any, for spill response throughout the areas affected by the proposed project should be identified and described in the DEIS. If there are none, this should be stated.

The DEIS should address how the prescribed procedures and necessary spill response actions would be enforced and if commitments to spill response actions will be conditions of permits. The DEIS should identify state or federal regulations that would compel the Applicant to implement effective spill control measures and spill response actions. Such regulations should be cited in the DEIS if spill control measures and spill response procedures are to be considered.

At present, it appears that only ADEC's equipment in Iliamna is currently available. A "container of supplies" does not sound adequate (DEIS 4.27-9); the DEIS should describe this in more detail and whether it is consistently maintained.

The DEIS should describe what spill response would look like if Iliamna Lake was iced over and there was a shoreline release, collision, capsizing, or other significant accident.

Section 4.27.2.5 Diesel Spill Scenarios

In the subsection for Soils, the DEIS ignores the potential impacts to archaeological sites from diesel spills. Archaeology sites are in the soil. If spills occur where there are archaeological sites, these sites will be directly impacted. Diesel would contaminate charcoal and burned wood that could be used to determine the age of sites through radiocarbon dating. Diesel would also destroy the possibility of analyzing stone tools for blood, fat, and other residues. The DEIS must describe how contaminated archaeological sites will be addressed. Recovering diesel "promptly" from the surface may impact archaeological surface sites by disturbing artifact context without proper planning. The DEIS should describe how impacts to archaeological surface sites during diesel spills will be avoided or minimized. Furthermore, the DEIS needs to address the potential impacts to cultural resources from all the types of spills and contamination from the proposed project listed throughout this section. Cleaning up spills, regardless of type, can adversely impact archaeological sites through contaminating the organic remains at sites and disturbing artifact context through soil removal.

The first paragraph of this section states: "Diesel spills from a tanker truck rollover and a marine tug-barge allision were analyzed for potential impacts. Large diesel spills from the Iliamna Lake ferry and a tank farm were ruled out as not realistic probabilities of occurrence, so were not selected for impacts analysis." (DEIS 4.27-10). The analysis on which these statements are based should be provided in the DEIS.

It is inappropriate for the DEIS to simply "rule out" these potential sources of diesel spills based on unsubstantiated claims that these are not "realistic probabilities." Such claims are strongly biased toward minimizing the potential impacts from diesel spills and releases.

It is unclear why spills from the ferry and the large proposed tank farm at the port were eliminated as not having realistic probabilities of occurrence. The basis for this determination should be clearly described in the DEIS. Any analysis used to select scenarios for evaluation should be presented. Even if the probabilities of a spill are low, if consequences of potential impacts are reasonably high, they should be evaluated and presented.

Although the probability of a "significant" (large) diesel spill is low, it should be evaluated on a theoretical basis. The quantity and impacts from a large spill, should one occur during the life of the proposed project, should be determined and evaluated in the DEIS.

In the tanker truck rollover scenario, a larger spill volume than 3,000 gallons should have been assumed. As discussed in Section 4.27.2.2, tanker trucks operating on the Dalton Highway are limited to one trailer, whereas those proposed to operate along the roads for the proposed Pebble Project would have three trailers, with a total of 19,050 gallons. Therefore, a 19,050-gallon spill should be assumed for the evaluation in the DEIS.

The assertion that diesel would be "rapidly transported downstream" and would be present in Iliamna Lake only as a sheen is overly optimistic and not supported by experience. (DEIS 4.27-11). Fate and transport of a diesel spill would be entirely dependent on the specific weather and hydrologic conditions and hydrogeomorphology of the water body that the diesel was spilled into. Diesel could collect in pools or shallow mudflats, collect in interstices of boulders or rocky environments, coat shorelines and float in thicker layers than sheen on the water. Aquatic and riparian plants, intertidal and benthic organisms, and birds and other wildlife could become coated with oil before it would have an opportunity to disperse or be recovered.

While this section states that "*adverse weather conditions could challenge early response procedures*," it does not describe in what manner or how these conditions would be dealt with. (DEIS 4.27-11). It also does not describe the actual frequency, nature and seasonal aspects of various adverse weather conditions that potentially could occur in the project area.

Based on field experience in this region, adverse weather conditions exist during a significant portion of the year, and the probability of adverse weather is very high during fall and winter. If a spill occurs on the lake during a big storm, the oil cannot be recovered, and the adverse effects of this oil would be seen and felt along much of the lake shoreline, down the Kvichak River, and possibly all the way to the river mouth.

Scenario: Diesel Spill for Tanker Truck Rollover.

Referring to the second paragraph of this subsection, these historical data probably understate the frequency, quantity, and impact of spills in Alaska. The unprecedented scale and aeral extent of the proposed project and remote nature of the areas affected do not lend themselves to comparison to other existing or historic projects in Alaska.

Referring to the third paragraph, this probability calculation seems to result in an unreasonably low frequency and indicates a strong bias toward understating the potential impacts of diesel spills in the areas affected by the proposed project. Considering the unprecedented scale and areal extent of the proposed project, it would be appropriate to assume a higher frequency of such spills over the life of the operation and quantify and evaluate the impact of such spills. These potential spills should be sited in a variety of vulnerable locations so that the USACE can take a hard look at the potential effects of diesel spills from all the tanker trucks traveling all the road miles during the life of the operation.

Potential Impacts of a Diesel Spill from Tanker Truck Rollover

Soils

Referring to the third paragraph of this subsection, the following statements are found: "Containment and recovery of spilled diesel would reduce the impact to soils. If diesel is recovered promptly and does not permeate the soil, impacts to soils could be negligible. Residual diesel that is not recovered from soil surfaces would likely evaporate or biodegrade

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from microbial activity." (DEIS at 4.27-12). This statement seems to under estimate the impacts of a diesel spill on soils by assuming that the diesel can be recovered "promptly" and before it mixes with the soil. In fact, it's very unlikely, in any event, that the impacts to soils would be negligible. This is an example of a statement that reflects bias with the intent of downplaying a serious environmental threat posed by the proposed project.

This subsection seems to imply that a 3,000-gallon diesel spill is not a problem, and that if the diesel is not promptly and effectively recovered, it will simply evaporate or biodegrade into some form of natural material in the soil. In fact, diesel in the soil would, in most cases, persist for several years. The information provided in this subsection is misleading, since contamination from diesel spilled over 70 years ago persists throughout Alaska, and the toxic effects on the environment persist as well.

It is highly unlikely that all the diesel remaining from a 3,000 to 10,000-gallon spill would just evaporate or degrade on its own in any reasonable period of time. Statements like this one need to be backed up by quantitative modeling for realistic winter conditions. If supporting information is not available, such statements should be removed from the DEIS. It should be assumed that soil remediation will be required for larger spills such as that described here. The cumulative impacts of multiple spills during the lifetime of the project on soils along the road corridor should be described.

Water and Sediment Quality

Surface Water. The following statement is found in the second paragraph of this subsection: "*If the spill were to occur away from surface water, and cleanup and recovery are successful, there could be no impacts to surface water quality*." (DEIS at 4.27-12). This statement reflects an optimistic bias with respect to the outcome of a 3,000-gallon diesel spill into a currently undisturbed, fully functioning, natural ecosystem. Such a spill would certainly impact surface water quality, and to say "there could be no impacts to surface water quality" is extremely disingenuous. The USACE should make a focused effort to remove this type of bias from the DEIS.

In the fourth and last paragraph of this subsection, the following statement is found: "*The duration of impacts would likely be a few days to a few weeks.*" (DEIS at 4.27-13). The basis for this assessment should be clearly described in the DEIS. The long-term and cumulative impacts associated with diesel spills in fresh water streams, ponds, and wetlands should be clearly and properly evaluated in the DEIS.

Sediment. In the second paragraph of this subsection, the following statement is found: "*If the spilled diesel were to reach a waterbody, sediments in the waterbody could be susceptible to hydrocarbon contamination from adsorption of diesel, although the magnitude of impact may not be measurable.*" (DEIS at 4.27-13). The DEIS should address potential impacts on micro-organisms, macro-organisms, and salmon larvae, fry, and juveniles in the waterbody. The USACE needs to consider long-term contamination of waterbodies affected by fuel transfer stations and equipment fueling that will occur throughout the areas affected by the proposed project. These impacts will persist during and long after the operational phase of the proposed project, and these long-term impacts need to be described and evaluated in this EIS.

In the third paragraph, the following statement is found: *"If a high volume of diesel is adsorbed onto sediment, the diesel trapped within sedimentary particles could persist for years. Diesel trapped within sediments could also re-contaminate overlying surface water at a later time, although this impact would likely not be measurable because of dilution."* (DEIS at 4.27-13). Because an impact is difficult measure does not mean it's not significant. The impact on aquatic organisms would be measurable in terms of mortality and reduced populations. Reasonably accurate measurements and useful data would rely on properly designed baseline studies. These baseline studies should be conducted, accurate measurements should be taken as needed, and the impact on aquatic organisms should be recognized and evaluated in the DEIS.

Groundwater. In the first paragraph of this subsection, the following statement is found: "In this scenario, assuming the anticipated spill response, spilled diesel would likely be recovered prior to impacting groundwater resources." (DEIS at 4.27-13). USACE should include the data or information this statement is based on. USACE should also explain whether this stamen can be supported considering all the possible spill and release locations in the areas affected by the proposed project. This statement and the assumption that the diesel would be recovered in a timely and effective fashion are overly optimistic and do not support an objective evaluation of the potential impacts to the natural, fully functioning ecosystem that would be adversely affected by a diesel spill. In the DEIS, the USACE needs to take a hard look at the potential impacts that would result from diesel spill at several locations within the areas affected by the proposed project.

It is stated here that "a *truck rollover has a reasonable probability of occurring at or near a stream.*" (DEIS at 4.27-12). The DEIS should provide a more specific estimate about what the probability of a truck rollover occurring at or near a stream is.

The estimate provided of the duration of impacts to water quality should be more quantitatively supported. This duration depends not only on dilution or evaporation, but on impacts to sediments and trapping in rocky substrates, and release and dissolution from these sources over time. Realistic estimates should be based on studies from similar environments rather than solely on chemical properties of diesel.

If there is a spill of 3,000 to 10,000 gallons of diesel fuel into a water body, contamination of sediments will certainly be measurable. Contaminated sediment will not likely be "diluted" by surrounding clean sediment, as it is not likely to move back and forth and mix freely. Nor is it likely to biodegrade rapidly under the conditions present in the affected environment. In pools, wetlands, or more quiescent environments, the long-term impact of diesel dissolving or being released as oil from sediments into overlying water may be significant and quite measurable.

Noise

Noise generated from spill response operations should include noise from helicopters, since helicopters would probably be necessary for timely spill response and cleanup actions in many locations within the areas affected by the proposed project. Potential impacts from helicopter noise should be described and evaluated in this EIS.

Air Quality

The first paragraph of this subsection states: "*Volatile organic compounds (VOCs), hazardous pollutants (HAPs) and greenhouse gases (GHG) pollutants resulting from a spill would be high in the immediate vicinity of the spill area, but would decrease quickly due to the dispersion of the spill itself, and dispersion of pollutants by the winds, waves, and currents. Ambient concentrations eventually return to pre-spill conditions within a relatively short period of time (BOEM 2012).*" (DEIS at 4.27-14). This refers to dispersion and dilution in the immediate area of a spill; however, the vapors would persist in the atmosphere. The DEIS should evaluate the potential short-term and long-term impacts to air quality and the atmosphere from spills and releases of hazardous pollutants and greenhouse gases.

The second paragraph introduces in-situ burning as a spill-response measure and states the following: "*In situ burning, a potential component of spill response strategy, would generate products of combustion (carbon monoxide, oxides of nitrogen, sulfur dioxide, particulate matter [PM], and black smoke). Ambient air quality would return to pre-burn conditions relatively quickly (BOEM 2012).*" (DEIS at 4.27-14). This considers only the immediate area of the spill and does not consider the impact of pollution buildup in the atmosphere and air quality of the region. These spill and recovery scenarios seem to rely too much on dispersion and dilution of contaminants and pollutants without regard to the overall effect that such releases would have on regional air quality, the atmosphere, and the environment.

In the third paragraph, the following statement is found: "*The extent of impacts would be limited to discrete portions within the project area where the spill took place*." (DEIS at 4.27-14). We disagree with this assessment, since the extent of these impacts would not necessarily be limited to the area where the spill occurred. As the diesel disperses, evaporates, burns, or otherwise changes form, it still impacts the media in which it comes to occupy. These far-ranging, long-term impacts should be recognized and evaluated in this EIS.

Wetlands, Aquatic Sites, and Vegetation

These estimates of how long it may take for the wetlands to recover are highly optimistic, and no sources are provided to support the estimates. Even in more temperate environments, wetlands are sensitive ecosystems that may never recover from a significant oil spill, or repeated small oil spills. If the wetland requires excavation and restoration, at least 10 years may be required to reestablish the wetland.

The first sentence states: "*Approximately 13 percent of the road corridor passes through wetlands or waterbodies, while the remainder is uplands*." (DEIS at 4.27-14). This estimate of 13 percent seems low and should be shown on maps to verify this apparent limited exposure of wetlands to the road system for the proposed project. The DEIS should identify what the "uplands" are that are not wetlands and whether these are areas that do not include wetlands, streams, ponds, and other areas connected to water resources that are potentially affected. Such areas should be described, and the potential impacts should be evaluated in this EIS.

In the first paragraph, the following statement is found: "*A spill into vegetated wetlands would primarily affect scrub-shrub and emergent vegetation, because these wetland types represent over 99 percent of the vegetated wetlands in the transportation corridor.*" (DEIS at 4.27-14). This estimate of 99 percent seems arbitrarily high and should be shown on maps to verify that this type of wetlands vegetation represents essentially all the vegetation in the wetlands in the areas affected by the proposed project.

In the second paragraph, the following statement is found: "*Where oiling of vegetation is not complete or does not extend into root systems or soils, little plant mortality would be expected, and* *impacted vegetation may recover within one or two growing seasons*." (DEIS at 4.27-14). This estimate of "one or two growing seasons" seems arbitrary and overly optimistic. The USACE should include the information on which such estimates are based in this EIS.

Birds

In the second paragraph of this subsection, the last sentence states: "*No population-level impacts from a single spill event are anticipated for any species*." (DEIS at 4.27-17). The DEIS should define "population-level impacts." This conclusion seems overly optimistic and unfounded. The information and evaluation on which this conclusion is based should be provided in this DEIS.

It should be recognized that population level impacts could occur depending on status of an affected species. Population level impacts to many species occurred because of the single event in such cases as the Exxon Valdez and Deepwater Horizon oil spills. In any event, even if population level impacts do not occur, the short-term and long-term impacts cannot be written off as not significant.

Invertebrates are important food resources for birds; therefore, the potential impacts to invertebrates need to be recognized and evaluated in the DEIS.

Fish

Impacts to invertebrates living in sediments or water are not sufficiently discussed or evaluated. Invertebrates are important food resources for salmon and resident fish. Sediment quality guidelines are established to protect aquatic invertebrates and the potential for impacts to them should be properly evaluated in the DEIS. In addition to PAH concentrations, oiling of invertebrates can cause narcosis-based effects and mortality.

The last sentence of this subsection states: "*Impacts to these fish and invertebrates could include potential mortality depending on the concentration and exposure time*." (DEIS at 4.27-17). This statement seems accurate; however, it doesn't conclude anything with respect to the potential impacts to fish, invertebrates, and other aquatic organisms that would be expected if the proposed project is permitted, constructed, and operated. The short-term and long-term impacts to fish and other aquatic resources are grossly understated throughout this section.

Needs and Welfare

As is true in so much of the DEIS, the Needs and Welfare section inappropriately focuses on Western employment opportunities. Here, the potential for spills to impact subsistence activities in the short term and long term should be discussed.

Subsistence

This section should be combined with Needs and Welfare, as discussed in previous comments. The present assessment underestimates the value of a pristine, unimpacted environment to Alaska Natives and other residents from both rural and urban areas. Diluted and partially cleaned up contaminated areas are very unlikely to ever hold the same cultural value as they previously did for subsistence and other traditional uses.

Health and Safety

As discussed above, the potential for small and large diesel spills on a routine basis is likely to create ongoing stress in surrounding communities, regardless of the actual number and frequency of occurrences or number and frequency of spill response actions that do occur. It would be nearly impossible for a community to evaluate the completeness or long-term safety of a response to such a spill or the low-level chronic exposures they may be subjected to from diesel vapors and exhaust due to truck traffic alone, which would be in additional to spills and releases.

Threatened and Endangered Species

This subsection states the following:

> *There are no federal TES that occur in the terrestrial portion of the project. Any spills that occur on land are anticipated to be dissipated prior to reaching the marine environment of Cook Inlet, where TES occur. Therefore, a diesel spill from a tanker truck roll-over along the transportation corridor is anticipated to have no impact on TES.* [DEIS at 4.27-17].

This statement over simplifies the event, which is the cause of an impact, and limits the scope and extent of the event. Then the DEIS concludes that such an event will have no impact on animals that are downstream of any spills that occur on land. This simplified description of an event and assumption that such a spill will be contained before it can spread into the environment fails to fully evaluate the consequences, both short-term and long-term, of a spill and multiple spills that adversely impact the ecosystem, reduce the populations of species throughout the food chain, and to ultimately affect an endangered species downstream and

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near the top of food chain. The USACE must include a complete and thorough evaluation in this EIS of the potential impacts to threatened and endangered species from spills and releases at several locations within the affected areas of the proposed project.

Scenario: Diesel Spill from Marine Tug Barge Allision

In the EIS, a word other than "allision" should be used for general reader comprehension. A commonly known word like "collision" would be a good alternative.

Since Appendix K4.27 will no longer be provided, the relevant statistical analysis and review of the data should be included in the EIS.

The DEIS should identify whether all the shorelines that the diesel would reach are sandy shorelines. This section discusses removal of contaminated sediment but does not address how rocky shorelines would be addressed, or whether they could be effectively decontaminated. Potential impacts to state parks and special areas (e.g. State refuges or critical habitat areas) and national parks and wildlife refuges are particularly of concern.

Potential Impacts of a Diesel Spill from Marine Tug Barge Allision

Water and Sediment Quality

The estimates of impact timeframes seem highly optimistic and should be supported with quantitative analyses. Use of dispersants, if this is part of the response scenario, can worsen water quality and sediment quality, as observed during and after the Deepwater Horizon oil spill response. The DEIS should clearly describe how it was determined that sediment contamination would not be measurable. The greatest contamination would likely be observed in the intertidal and nearshore sediments, where the impacts to aquatic life species that frequent or depend on nearshore and intertidal would be significant.

Marine Environment

In the third paragraph of this subsection, the following statement is found: *"The duration of impacts would probably be on the order of 2 to 3 weeks or less before spill recovery efforts and natural weathering processes removed the spilled oil."* (DEIS at 4.27-20). This estimate seems arbitrary and very optimistic, and is not based on published literature about the long-term fate and effects of diesel spills. The residual contamination in the water column should be recognized, described, and evaluated in the DEIS. The information on which this estimate is based should be provided in the DEIS.

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On-Shore Environment

In the second paragraph, the last sentence states: "*Impacts would be similar to those addressed above for the tanker truck rollover scenario.*" (DEIS at 4.27-21). The impacts from a marine spill of diesel to a coastal pond and nearshore water resources should be described here, rather than referring the reader back to another section that pertains to a different scenario and different impacts to different resources.

Noise

The effects of increased noise on birds and mammals, especially during breeding, nesting, and calving seasons, as well as all other life phases, should be recognized and evaluated in this EIS.

Air Quality

In the third paragraph, the last sentence states: "*The extent of impacts would be limited to near the spill location.*" (DEIS at 4.27-21). We disagree with this assessment, since the extent of these impacts would not necessarily be limited to the area where the spill occurred. As the diesel disperses, evaporates, burns, or otherwise changes form, it would still impact the media in which it comes to exist. The DEIS should recognize and evaluate these far-ranging and collective impacts. The DEIS should include a complete and thorough evaluation of potential impacts and take a hard look at collective and cumulative impacts.

Marine Mammals

Please explain this statement: "*If a large diesel spill occurs, marine mammals will be deterred away from contaminated areas.*" (DEIS at 4.27-23). The DEIS should address whether this means they will naturally avoid the area, or that responders will attempt to deter them from the area. If the latter, the DEIS should identify if this a legal and/or effective approach and if it would have adverse effects on the marine mammals as well.

In the fifth paragraph of this subsection, the following statement is found: "*Non-TES marine mammal species could be impacted by this diesel spill scenario.*" The DEIS should more fully describe the magnitude of effects and the scientific basis for this statement. Based on the description above, the magnitude of impacts from a diesel spill is can range from severe and significant to moderate. The scientific basis that supports such conclusions should be provided in the DEIS.

Birds

This section is much more specific than many of the other descriptions of impacts associated with a spill and should be used as a model for improving the discussions in the other sections. However, the DEIS should include scientific support for the statement that mortality of several hundred Rock Sandpipers would not present a population-level impact for this species of conservation concern.

In the eighth and last paragraph of this subsection, the following statement is found: "*Typical spill response actions are expected to be relatively small in scale, with impacts limited to the vicinity of the spill site, and would therefore affect a limited number of birds*." (DEIS at 4.27-25). The DEIS should more specifically describe what constitutes a "limited number of birds." This conclusion seems to downplay and discount the potential impacts to birds and the effect on bird populations.

Fish

The title of this section should be modified to Aquatic Life (and other similar sections). Since the life-cycle of most marine invertebrates is 30 days or less, any contamination that remains for that long may have significant population-level impacts in the area where the contamination is present. In addition, contamination may persist in oiled rocky shorelines longer than in open water. Larval fish mortality would certainly be high, and in many cases where outright mortality does not occur, malformation of organs and other teratogenic effects are observed that compromise later development of the fish. There is considerable scientific literature on the effects of petroleum spills on aquatic life. The DEIS should reference this literature to support conclusions about impacts.

Throughout the entire section, there are varying estimates of the duration of impacts that seem to differ among resource sections. The reasons for these differences are unclear. Regardless of the duration cited, it should be placed in the context of the organism's lifecycle, availability of food resources, or other significant impact rather than using general descriptors like "short" or "long."

The fourth and last paragraph of this subsection states the following:

> *Intensity of the impacts would vary based on the location of the spill, and the species and life stage present. Impacts are not likely to last longer than 30 days in open water but could be of longer duration in areas physically sheltered from wind, wave, and tidal influences. In these protected areas, there is a potential of mortality to larval fish such*

> *as herring and invertebrates depending on the concentration and persistence of the contamination.* [DEIS at 4.27-26].

The DEIS should clearly describe the scientific basis for this conclusion with respect to impacts on fish. The statement that "*Impacts are not likely to last longer than 30 days in open water . . .*" is arbitrary and has no basis in fact.

In our view, the literature clearly supports a conclusion that impacts could be significant and long-term; however, this is not recognized or stated in this DEIS. The DEIS should include complete and thorough evaluations of the potential impacts to fish and take a hard look at the long-term and cumulative impacts of multiple spills and releases on fish and fish habitat in the areas affected by the proposed project.

Subsistence

In general, it is a fallacy that apparent rapid response to a cleanup and good communication will suffice to overcome community concerns regarding contamination after a large spill. This is especially true for Alaska Native communities, who hold cultural values that particularly value wilderness and uncontaminated resources. Areas impacted by a large spill are unlikely to ever be viewed in the same manner as these areas were previously. This comment applies to all similar subsections in this section.

Threatened and Endangered Species

Humpback Whale. The first sentence states: "*The number of humpback whales in Cook Inlet is fairly low, and detrimental impacts to a low number of whales are not anticipated to have population-level effects.*" (DEIS at 4.27-27). The number of humpback whales is low, which is why it's classified as an endangered species. The impact on an endangered species could be greater than moderate if it affects one animal or reduces the population by one. The DEIS should describe potential impacts to the humpback whales' food supply. The USACE should ensure that a thorough and objective evaluation is conducted in the DEIS for all potential impacts to humpback whales and all threatened and endangered species.

At the end of the same paragraph paragraph, the following statements are found: "*The duration of potential direct impacts from the diesel spill would be short (10 to 20 days), because diesel rapidly evaporates, disperses, and is broken down. However, the duration may last longer due to consumption of contaminated prey, and a temporary reduction of localized prey populations.*" (DEIS at 4.27-27). The DEIS should describe how the duration of 10 to 20 days was determined.

This statement about a "short" duration should be deleted. In addition to direct impacts, indirect impacts and long-term and cumulative impacts to humpback whales should be evaluated in the DEIS.

Fin Whale. In the first paragraph, the following statement is found: "*The duration of impacts would be moderate; the duration of impacts would be short (10 to 20 days), because diesel rapidly evaporates, disperses, and is broken down . . .*" (DEIS at 4.27-27). This statement should be revised based on a thorough and objective evaluation of potential impacts.

4.27.3.2 Fate and Behavior of Released Gas.

The first sentence states: "*Potential gas leaks from the proposed pipeline would be released into the surrounding soil or water column, rise buoyantly up to the surface, and dissipate readily into the air.*" (DEIS at 4.27-33). The DEIS should evaluate the short-term and long-term impacts on air quality and the atmosphere. The potential impacts from greenhouse gas emissions from the proposed project need to be quantified and evaluated in the DEIS.

4.27.4.3 Fate and Behavior of Spilled Concentrate

Not only would concentrate that was spilled leach metals and acid over the long term, in the short term, these fine-grained materials would have high concentrations of metals that would exceed soil and sediment criteria, and this would have direct impacts on plants, invertebrates, and vertebrates (like fish and birds), contacting or ingesting these particles.

Concentrate Solids vs. Concentrate Slurry

This section states that concentrate solids spilled into flowing water would require in-water recovery efforts. This would be very difficult, particularly in the relatively rocky streams surrounding the proposed Pebble Project. Fine-grained material would make its way into the interstices between rocks and become difficult to recover and some material would mix with existing sediments.

The DEIS needs to be revised to include information that supports the anticipated recovery efforts. Potential recovery efforts should be described in detail to allow for a thorough and unbiased evaluation of the potential impacts. The effects of recovery on streams should be evaluated, and the distance that the impacts will carry downstream should be estimated. The period over which impacts might occur and persist should be estimated. Precedents or case studies in the literature that support recovery estimates and describe impacts should be referred to and cited.

Sedimentation and TSS

Fine-grained particles that make their way downstream, in addition to creating a cloud of TSS in the water, would also contain very fine-grained metals particles, which would be toxic to most fish and invertebrates.

Metals Leaching

Metals such as copper do not have to leach out of the solid particles to be toxic. Very fine-grained particles may be ingested by fish, shellfish, or invertebrates and be released inside their bodies. Even if metals required years to decades to leach into the surrounding environment, they will certainly be present for that long, and once released into water bodies, these metals will be largely unrecoverable.

4.27.4.4 Historical Data on Concentrate Spills/Spill Frequency and Volume

More information is needed to evaluate whether the Red Dog Mine is an appropriate analogue for proposed Pebble Project trucking. The point is made that most spills along the Red Dog Mine road did not impact water resources, but it is not stated whether the Red Dog Mine road crosses streams as frequently as would the proposed transportation corridor for the Pebble Project. The one spill into water resources on the Red Dog Mine road is apparently not cleaned up yet, not boding well for similar spills that could occur along the proposed Pebble Project road. The amount of concentrate that could spill in a given incident using the triple-trailer trucks also appears to be much larger than that at the Red Dog Mine.

4.27.4.7 Concentrate Spill Scenarios

Potential Impacts of a Concentrate Spill from Truck Rollover

Water and Sediment Quality

Fine-grained particles do not have to be soluble to have a water and sediment quality impact. Fine particles can easily be ingested by aquatic organisms, released within the body, and have a toxic impact on the organism. For these reasons, sediment quality guidelines are based on bulk concentrations, not soluble concentrations.

It is unlikely that the concentrates could be "promptly removed" from the waterbody. As acknowledged earlier in this section, removal of the concentrate from water bodies would be difficult, if not impossible. Dredging is generally not practicable from remote rocky streams. The concentrate, once spilled, would remain entrained in the sediments and interstices between rocks for decades, eventually leaching metals and acids into the water.

Potential impacts to water and sediments must be fully identified and thoroughly evaluated using established scientific methods. Claims such as "*concentrates will be promptly removed*" should be replaced with well-supported estimates of the time it could take to remove the spilled material, what percentage of the material could be recovered and removed, and what are the potential short-term and long-term impacts from the spill. The type of information should be provided for each spill and release scenario, the DEIS should be revised to include this new information, and the revised DEIS should be released to cooperating agencies and the public for review and comment.

Fish

As noted above, there are many incorrect assumptions in this section. Fine particles containing contaminants toxic to fish (such as copper) can be ingested through the water or across the gills. Once the concentrate has become entrained in the bedload, it would remain available to benthic organisms and bottom-feeding fish, who ingest sediments as part of feeding. Overlying water does not prevent oxidation of sulfides in sediments; when oxygen is present, there is an oxic layer of sediments that can release metals from sulfide form. Both the sulfides and the metals released are toxic to benthic organisms and fish, depending on the concentration present.

Threatened and Endangered Species

The note towards the end of this section regarding copper bonding with organic matter is entirely random and not necessarily applicable to the release scenario being evaluated. Copper bonds with a variety of substances, but its toxicity in water depends on the amount of copper released compared to available sequestration mechanisms. In the case of a large spill, the amount of copper released would likely overwhelm any natural bonding capacity of the water body.

The fate and transport of copper and other toxic metals liberated and released during construction, operation, and post-closure phases of the proposed project needs to be determined and described, and the potential impacts from these metals needs to be evaluated in the DEIS. The DEIS should be revised to include this information, and the revised DEIS should be released to cooperating agencies and the public for review and comment.

Commercial and Recreational Fishing

None of the information presented suggests that a large spill of concentrate into a water body would be "*of low magnitude, in a localized area, and of limited duration with no population-level* *impacts*." (DEIS at 4.27-49). Due to the size of the trailers being towed, the amount of material spilled could be large and could completely overwhelm the carrying capacity of a stream and its fish populations for several decades. This impact would result in significant long-term and cumulative impacts.

Aesthetics

This is the first time in this section that aesthetics has been mentioned; it should be added to the diesel fuel spill sections as well. For any spill scenario, the initial sight and odor of the material spilled is one aspect of the impact. Spill response activities create an additional disturbance. Beyond these impacts are the long-term aesthetic impacts resulting from the disturbance of the landscape required to clean up the spill, which may include removal of soil and vegetation, building access to streams or other remote locations, and other activities that damage and degrade the affected area. In this climate, such areas may not visually recover to a revegetated or unaffected state for many years.

Concentrate Slurry Pipeline Rupture

The USACE should remove all references to Appendix K4.27 and include the appropriate information in this section.

See comments above regarding the effects of the slurry concentrate in the environment and particularly in surface water bodies, which would be expected to be similar in nature but greater in magnitude than those of the dry concentrate.

4.27.6 Tailings Release

It is not true that the Applicant's proposal eliminates the need for tailings ponds that would exist in perpetuity. The pyritic tailings will be returned to the open pit lake, whose water level will need to be maintained in perpetuity to avoid release of toxic water to the surrounding watersheds. This all but guarantees that at some point, there will be a release, since maintaining such a system in perpetuity is an impossibility. In addition, the bulk tailings dams will always be present above the watershed, representing an inevitable release scenario of their own – it is only a matter of time. However distant in the future this may be, it still represents an unacceptable impact to the environment.

As stated in this DEIS: "*A 'failure' of a TSF refers to the unintended release of tailings fluid and/or solids, and could result in impacts to the downstream environment.*" (DEIS at 4.27-62). As noted in later comments on this section, the DEIS only addresses a select number of "failures" resulting in unintended tailings fluid and solids releases that could result in impacts to the downstream environment. The DEIS is incomplete and needs to be revised to address several other significant failure modes that could likewise result in impacts to the downstream environment.

4.27.6.1 Bulk Tailings and the Bulk TSF

According to the DEIS:

> *PLP is proposing to separate mine tailings into bulk tailings, which are relatively inert; and pyritic tailings, which have higher potential to produce acid and leach metals. . . . Because the process of mineral separation is inherently imperfect, a small percentage of unrecoverable sulfide minerals and other metals would remain in the bulk tailings, so that bulk tailings would contain a small percentage of PAG material and have a relatively low potential for ARD and ML compared to pyritic tailings.*

The DEIS use of the term "relatively inert" is not meaningful, and the use of this term appears to be biased from a scientific standpoint as the analysis should not be about a comparison, but rather whether the bulk tailings have the potential to produce ARD and ML.

As stated later in this section of the DEIS:

> *Modeling results indicate that the concentrations of the following metals would exceed applicable WQC (as defined by Alaska Water Quality Standards [WQS], 18 AAC 70): antimony, arsenic, beryllium, cadmium, copper, lead, manganese, mercury, molybdenum, selenium (a metalloid), and zinc (Knight Piésold 2018a) (see Appendix K4.18, Table K4.18-3). Water quality parameters, including total dissolved solids (TDS), alkalinity, hardness and sulfate in the bulk tailings supernatant, are also not expected to meet the respective WQCs. The contact water used to make up the thickened bulk tailings slurry would also likely contain elevated concentrations of some metals and other constituents that would exceed water quality criteria.* [DEIS at 4.27-63].

This description is contradictory to the suggestion that the bulk tailings is "relatively inert." The DEIS should clearly state that <u>the bulk tailings do have the potential to produce ARD and ML and that unintended release of supernatant and/or leachate-seepage from the bulk tailings during operations or post-closure could result in impacts to the downstream environment</u>.

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Accordingly, the DEIS must be revised to identify and address release of supernatant and/or leachate-seepage from the bulk tailings as a substantive failure mode.

Also, antimony and arsenic in addition to selenium are considered metalloids. Consistent with USGS practice, the DEIS should simply recognize all these elements as "metals" and note that some of them (e.g. metalloids and semi-metals) can have either a positive or negative charge, and therefore, unlike other metals, can be highly soluble at both acid and neutral-alkaline conditions.

According to the DEIS: "*Because bulk tailings have a low concentration of PAG material, they would not require subaqueous storage.*" (DEIS at 4.27-63). This infers that the bulk tailings do have the potential to produce ARD and ML. Based on the information otherwise contained in the DEIS, the reason the bulk tailings are not being stored subaqueous is due to limited storage capacity within the post-mining open pit for subaqueous storage and prioritizing the pyritic tailings for subaqueous disposal because these materials have a higher potential for ARD and ML.

The retention of the bulk tailings TSF as a subaqueous facility post-closure would present an ongoing geotechnical hazard that can be eliminated by dry closure of the bulk tailings and should be performed for that purpose, but it does not preclude the need to address the potential for long-term ARD and ML from the bulk tailings.

The next sentence in the DEIS suggests:

> *Therefore, the main (north) embankment of the bulk TSF is proposed to operate as a pervious, flow-through zoned rockfill and earthfill embankment that would allow excess fluid in the tailings to drain out through the seepage collection system, and then either re-used in the mill process, or treated and released.* [DEIS at 4.27-63].

The seepage would be treated prior to release, so as suggested, the relation the DEIS draws in this paragraph to subaqueous storage is not logical.

According to the DEIS:

> *The bulk tailings that are drained and not fluid-saturated would have a consistency that would flow similar to molasses. These tailings would be quite viscous, and would*

> *not readily flow if spilled (MEND 2017). Tailings deeper in the facility that would be fluid-saturated would exhibit more fluid behavior, and would flow more readily as a slurry if spilled.* [DEIS at 4.27-63].

The DEIS should note that the tailings in the southern portion of the TSF would be fluid-saturated therefore a failure of the bulk tailings TSF would be likely to result in rapid flow of tailings. The PDEIS uses the term "spill" where it should also be identifying a more catastrophic failure. The PDEIS appears to be using the term "spill" to avoid the acknowledgement of the potential for a catastrophic failure.

In addition to identifying the water quality criteria that would be exceeded in the supernatant and contact water, the sediment quality criteria that would be exceeded in the tailings material itself should be identified to evaluate the impacts in the event of a release.

4.27.6.2 Pyritic Tailings and the Pyritic TSF

The DEIS states:

> *Several years after the close of mine operations, the pyritic tailings would be pumped into the open pit, which would then be allowed to fill with water, so that the pyritic tailings would be permanently stored sub-aqueously. Perpetual storage in the pit would reduce the potential for a spill of pyritic tailings after the close of operations.* [DEIS at 4.27-64].

The DEIS should avoid the use of uncertain determiners and pronouns such as "several" which lead to uncertainty, and instead, to be precise where possible, should provide the expected number of years or range of years (based on the mine reclamation and closure plan).

As some minerals containing arsenic, selenium and other metals may still be soluble in subaqueous reducing conditions the DEIS should identify the potential for and fate and transport of those metals from the pyritic tails into the pit lake water column and their potential for discharge.

In addition to identifying the water quality criteria that would be exceeded in the supernatant and contact water, the sediment quality criteria that would be exceeded in the tailings material itself should be identified to evaluate the impacts in the event of a release.

4.27.6.3 Fate and Behavior of Released Tailings

For the various factors affecting the severity of a release, the probability of each factor should be further described. For example, the probability of release onto dry land rather than into a water body should be described in the DEIS. Each factor should be addressed in this more quantitative manner.

In describing "Water Content within the TSF" the DEIS states:

> *Under otherwise normal operating conditions, a spill from the well-drained tailings beach of the bulk TSF would be considered a relatively dry spill scenario, in which the tailings would remain a viscous mass, not capable of flowing great distances.* [DEIS at 4.27-65].

Nearly all TSF failures in our experience, as documented by ICOLD (International Commission on Large Dams) and others, were due to either of two circumstances, the most common being "operating otherwise from normal operating conditions," and the other being "due to previously unknown conditions or other information." The DEIS should describe and address the potential for catastrophic failures associated with the TSF and water storage facilities based on the assumption of a reasonable worst-case failure scenario that would be likely to be caused or precipitated by abnormal operating conditions and/or unknown conditions or information not identified in the EIS or other studies.

In describing "*Speed/Duration of Release*" the DEIS states:

> *If a spill of tailings were to occur slowly, such as a slow leak through one of the embankments, personnel would have time to respond, contain the spill, and repair the leak. If response is prompt and the duration of the spill is brief, the spilled tailings would likely be of relatively low volume and would not travel far. A long-duration spill could allow a large volume of tailings to be released, and to travel a significant distance downslope and into waterbodies.* [DEIS at 4.27-65].

This section demonstrates the confusing use of the terms "spills" and "leaks" relative to whether tailings solids or tailings supernatant are being described. For example, a "slow leak through one of the embankments" would typically not involve a "spill of tailings" solids as described in the DEIS but would instead involve a leak of tailings supernatant or leachate, both of which are fluids. There would be no actual "spill of tailings." The exception would be if the embankment showed indications of the leakage associated with "piping." In this case there may or may not be time to respond as described in the DEIS, since "piping" could result in a catastrophic failure and release both tailings solids and supernatant.

The DEIS should distinguish between a release of supernatant (from overtopping), seepage from the TSF embankments (particularly post-closure), tailings spills (such as from a pipeline), and catastrophic release of tailings (such as from an embankment failure or overtopping). The DEIS should note that a catastrophic release can result in either a small or a large amount of tailings supernatant and solids being mobilized depending on the site-specific circumstances.

The DEIS should describe a scenario in which the response to a spill is not prompt, which is likely to occur frequently. Based on this scenario, the DEIS should identify and evaluate the potential impacts of a spill that, due to a delayed response, is allowed to release, flow, and spread for an extended period.

In describing "*Summer versus Winter*" the DEIS states:

> *Frozen rivers would not transport spilled tailings downstream. Tailings spilled during frozen conditions would therefore accumulate closer to the TSF, and would be easier to recover. Frozen soils would not be permeable, so that tailings slurry would not be able to percolate downward into soils and frozen sediments.* [DEIS at 4.27-66].

This suggests in some way that a winter spill would be less problematic to recover. In reality, based on our experience in mine cleanup, the opposite would be true, as it is doubtful that any mitigation could take place during winter conditions and once the frozen tailings thawed, they would behave much like tailings spilled during the summer season, only subject to mobilization by the spring freshet.

In describing "*Mode of Failure*" the DEIS states "*The behavior of spilled materials is dependent on the way in which a spill occurs*" and then identifies the most common <u>geotechnical</u> failure modes referencing ICOLD. (DEIS at 4.27-66). These modes as noted are catastrophic failure modes. The DEIS should also address modes of failure associated with long-term discharge of leachate from the bulk tailings TSF.

<u>Tailings Slurry Release</u>

In describing "*Tailings Slurry Release*" the DEIS states: "*Elevated metals from the fluid would affect water quality in the short term, until all the fluid is flushed downstream and diluted, as previously described.*" (DEIS at 4.27-67). Based on our experience in cleanup of tailings at other sites, such as Mount Polley and the Clark Fork River Superfund site, impacts to water quality will continue as long as tailings solids with the potential for ARD and ML are present. As a result, the effects on water quality are not limited to "short-term" impacts.

This is further emphasized in the DEIS in this subsection under "*Acid*" and "*Tailings Solids*" where the DEIS states:

> *In the event of a release of bulk or pyritic tailings into the environment, acid could be generated from unrecovered tailings solids, if tailings remain exposed to air over a period of years to decades. If tailings are recovered, no acid would be generated that would impact the downstream environment.* [DEIS at 4.27-67].

The DEIS should address the following issues: the practicability of tailings recovery; what if any contingency plans have been prepared or will be required to conduct such a recovery; the cost of such an activity; and how the cost would be assured to not be a liability to taxpayers.

The discussion of xanthate is unclear. The DEIS should describe if xanthate is only present in the fluid, or if it also is present in the tailings. The DEIS should evaluate how far downstream xanthate could it travel before it would be neutralized (it is presumably highly toxic along the way). If it is present in the tailings, it could be released over a longer period of time into the overlying water. This potential impact should be recognized and evaluated in the DEIS.

Sedimentation and TSS

This section would make sense if the volume of tailings spilled into a water body did not completely overwhelm the amount of water present. In that case, it could create large deposits of muddy or silty tailings in contact with the water for a long period of time, as opposed to TSS flowing within a natural water body. The amount of TSS that could be expected to be generated throughout the water system should be estimated for comparison to water quality criteria and to evaluate impacts on aquatic life.

Acid

Tailings Fluids

In this subsection, the DEIS provides insufficient recognition and evaluation of potential impacts to water quality and aquatic organisms due to elevated metals concentrations in water. If water quality impacts occur, as are likely, for decades, the area and duration of impacts must be clearly stated. There is enough potential for long-term and cumulative impacts due to tailings releases to result in catastrophic decades-long effects on surrounding watersheds.

Tailings Solids
These statements about benthic invertebrates are incorrect. Metals do not need to be dissolved to have toxic effects on invertebrates, many of which ingest sediment into their bodies, filter feed, or otherwise come into contact with bulk particles.

Bottom-feeding fish and dabbling ducks likewise are exposed directly to toxins in bulk sediments. Since the mine tailings could not be readily recovered from the watershed, their impacts would likely occur over decades, well beyond the lifecycles of most aquatic organisms. Other watersheds impacted by mine tailings, such as the Clark Fork River, have essentially been rendered lifeless.

<u>Metals</u>
Tailing Fluids
In describing "*<u>Metals</u>*" under "*Tailings Fluids*" the DEIS states:

> *In the event of an unplanned release, these metals would be introduced into the downstream waters, and would cause downstream waters to exceed WQC. The released fluid would be diluted and flushed downstream. Depending on the volume and the rate of release, the downstream water quality would be in exceedance of WQC for an unknown length of time and an unknown distance before the released fluid is sufficiently diluted below water quality exceedance.* [DEIS at 4.27-68].

The DEIS should include an analysis of a reasonable worst-case scenario or scenarios for an unplanned release of tailings fluids that quantifies both the nature and extent of the release and the impacts.

Tailing Solids
In describing "<u>Metals</u>" under "*Tailings Solids*" the DEIS states:

> *ML is a natural process in which metallic minerals dissolve through chemical weathering, releasing the metals into the water. However, metallic minerals are not readily soluble in water, and the ML process occurs very slowly over years to decades.*
> (DEIS at4.27-68).

This statement is inaccurate as metals associated with some minerals may be highly soluble in water (e.g. copper associated with the mineral malachite). While this statement is more accurate with respect to "metals associated with sulfide minerals" in some cases sulfide minerals such as pyrite and arsenopyrite can show rapid oxidation leading to leachate containing metals occurring in days to weeks (e.g. Golden Sunlight Mine, Montana) rather than years to decades as described in the DEIS.

The DEIS focuses solely on "*water quality criteria*" in this section (and throughout). The analysis should describe impacts on not only water quality, but also on the larger watershed and ecosystem functions.

In describing "*Metals*" under "*Tailings Solids*" the DEIS states":

> *In neutral pH waters, ML would be a very slow process. Copper present in the tailings, for example, would not readily leach into surface waters, but would likely require decades of chemical weathering to render it sufficiently bioavailable to impact benthic invertebrates and fish.*
> (DEIS at 4.27-68 to 4.27-69).

The DEIS should provide a more detailed analysis, including references for this issue. Benthic micro-invertebrates as well as fish, which are not addressed in this DEIS, are highly sensitive to copper and other metals.

Mining can increase metal concentrations in water by several orders of magnitude compared to uncontaminated sites (ATSDR 1990, USEPA 2000, Younger 2002), and because Cu can be highly toxic to aquatic life (Eisler 2000).

Further studies are needed to improve understanding of 14 potential effects of ingested Cu because once released into the environment Cu can accumulate in aquatic sediments and continue to recycle into aquatic food webs (Woody and O'Neal 2012).

If the proposed project is permitted, constructed, and operated, A more robust evaluation of the liberation, release, and accumulation of copper and other toxic metals into the waters of this ecosystem must be developed and included in a revised DEIS.

4.27.6.4 Historical Examples of Tailings Releases

The descriptions of recent mining releases in the 20th Century significantly understate the level of damage done to watersheds. The final paragraph is presented without any documentation and needs to be expanded with documented examples.

Relative to the Mount Polley TSF failure, the DEIS states: "*Other recent tailings dam failures in China, Mexico, and Australia demonstrate that modern, well-engineered tailings facilities are subject to failure.*" (DEIS at 4.27-69). In fact, it has been noted that major failures continue to occur at a rate of approximately two per year. Given that the DEIS recognizes this probability, the DEIS should fully and properly analyze a catastrophic bulk tailings TSF failure in addition to a pipeline spill. The lack of analysis of a catastrophic bulk tailings TSF failure constitutes a significant fatal flaw of the DEIS.

According to the DEIS:

> *Due to improved modern TSF management practices, environmental regulations and public demand, tailings spills are now more routinely recovered and cleaned up, so that the potential for severe long-term impacts from unrecovered tailings is likely lower now than in the past century. Small- to moderate-volume tailings spills from the proposed project would likely be recovered to conditions in compliance with state regulations.*
> (DEIS at 4.27-70).

Modern TSF management practices are unrelated to tailings spills now being "more routinely recovered and cleaned up." The increased likelihood of cleanup of TSF failures is due to environmental regulations and public demand; however, this could be at public expense if the project operator that's responsible for the cleanup fails financially, and adequate funds are not available from the project operator to clean up the environmental damage caused by the TSF failure. Furthermore, the cleanup is never complete and does not preclude long-term environmental degradation that results from a TSF discharge.

The DEIS should address requiring a comprehensive environmental liability insurance policy as mitigation for any unexpected failures or other releases that result in unpredicted adverse impacts to water quality or other resources.

4.27.6.5 Probability of Failure

As stated in the DEIS, "*Determining the probability of failure of tailings dams is difficult.*" (DEIS at 4.27-70). The DEIS should therefore, as previously recommended, analyze a catastrophic bulk tailings TSF failure in addition to a pipeline spill. The analysis should be conducted in accordance with the Canadian Dam Association and other recommended guidelines for TSFs and should include both a "worst-case" as well as "blue-sky" failure scenario.

Although the probability of failure in the near term is difficult to estimate, the probability approaches 100 percent over time. Consequently, the potential impacts of a large failure and smaller failures over time should be presented and evaluated in the DEIS. Since the timeline for the proposed project extends in perpetuity, such failures will occur over time. There is no way of knowing in advance the effectiveness of human oversight or the degree of human error that might occur throughout the lifetime of the proposed project, which includes design, construction, operation, reclamation, closure, and post-closure periods – during all these periods there is the potential for failure, since the bulk TSF will be present in perpetuity.

According to the DEIS:

> *Estimates of the probability of failure of tailings dams include: one failure for every 2,000 dam-years (one dam-year is the existence of one dam for one year) (Chambers and Higman 2011); one failure for every 2,041 dam-years (Peck 2007); one failure every 714 to 1,754 dam-years (Davies et al. 2000; Davies 2002); and one failure every 2,500 to 250,000 dam-years (EPA 2014). These leading estimates all indicate that the probabilities of failure are very low.*
> (DEIS at 4.27-70).

The interpretation of this data suggesting that the "probabilities of failure are very low" is incorrect. In fact, the data should be interpreted as suggesting that the ultimate probability of failure of a TSF, if left susceptible to failure, is certain. This is the primary reason for the recommendation by the Mount Polley Independent Expert Review Panel of Filtered Tailings as BAT (Best Available Technology).

As noted in Appendix I: B.C. Tailings Dam Failure Frequency and Portfolio Risk[1], given time, all TSFs will fail unless landform (stable) closure is achieved. For new TSFs, "Restricting future growth of the inventory can be achieved through tailings technologies that avoid water storage in the first place." Rather than downplaying the likelihood of failure, the DEIS should instead fully consider filtered tailings as recommended by the Mount Polley IERP, and otherwise describe and evaluate a catastrophic failure of the TSF.

According to the DEIS: "*Those TSFs that have been shown to be the most robust and to not experience failures are those that have periodic technical review by qualified engineers throughout the operational lifetime.*" (DEIS at 4.27-71). This statement has not been demonstrated in practice. The Mount Polley TSF had periodic technical review by qualified engineers throughout the operational lifetime. Those technical reviews proved to be inadequate and did not result in the recognition of potential risks, or those risks were underestimated or ignored. While this should be the case, there is no assurance the ADSP required review would result in a different outcome. The most robust TSFs are those where the responsible corporation has shown the capacity and commitment to ensure TSF safety, such as corporations that adhere to the ICMM Tailings Management Protocol (https://www.icmm.com/en-gb/environment/tailings).

The ultimate operator of the proposed project, including the TSF, is unknown and could be an untested entity that has not demonstrated the capacity and commitment necessary to ensure TSF safety. This would compound the risk of a TSF failure in the near term. In any case, based on the history of TSF and the long-term certainty of a TSF, the DEIS must include scenarios for a catastrophic massive TSF failure in the long term and less TSF failures in the near term. Based on the scenarios, the USACE must take a hard look at the potential impacts of these failures. This thorough evaluation of TSF failures should be included in a revised DEIS, and the revised DEIS should be released to cooperating agencies and the public for review and comment.

4.27.6.6 Risk Assessment for the Proposed Embankments

It is difficult to assess these risk assessments without the results of the expert panel FMEA report, which was to be provided in Appendix K4.27, which is now not available for review. The DEIS should include a summary of the results and a link to the report.

As noted by the DEIS: "*The FMEA process can be used to strengthen engineering design, inform subsequent stages of site investigation, and provide input for the dam permitting process.*" (DEIS at

[1] https://www.mountpolleyreviewpanel.ca/sites/default/files/report/AppendixI_BCTDFFrequencyandPortfolioRisk.pdf

4.27-71). The DEIS also states *"The current level of embankment design for the proposed project is at a very early phase, considered a conceptual phase. Site investigation and engineering plans are still ongoing. The ADSP would require additional risk assessment in order to issue a Certificate of Approval to Construct a Dam (ADNR 2017a)."* (DEIS at 4.27-71).

The additional risk assessment required by ADSP should be conducted and provided as part of the DEIS. Without this additional risk assessment, the DEIS is deficient. It is evident that the very early conceptual phase information available for the level of analysis in the DEIS is inadequate and has not resulted in the type of FMEA analysis that would ultimately benefit the NEPA process as well as the dam permitting process.

According to the DEIS:

> *In October of 2018, USACE hosted an EIS-Phase FMEA workshop to assess the likelihood of a spill and the severity of potential environmental impacts from the major proposed embankments . . . The expert panel evaluated the design of each embankment, and assessed the likelihood of a wide range of potential failure modes.*
> (DEIS at 4.27-71 to 4.27-72).

The DEIS references Appendix K4.27 for the EIS Phase FMEA report, which has recently been withdrawn as an appendix and will instead be a report referenced in the DEIS. We were able to locate "KP 2018o" consisting of a letter report from Knight Piésold to Pebble Limited Partnership dated December 13, 2018 and titled *Pebble Project: EIS-FMEA Failure Scenario for the Bulk Tailings Storage Facility*. According to the document "*The failure scenario selected for the Bulk TSF is "Earthquake (greater than the OBE) causes shearing of tailing delivery lines along the embankment resulting in discharge (AECOM 2018).*" The References section of the report identifies the document as "*AECOM. 2018. Pebble Project – EIS-Phase FMEA and Selection of Spill Scenarios (In-Progress).*" We attempted to find this document on the project website (https://pebbleprojecteis.com/) but were unable to locate it.

The FMEA panel typically reviews and decides on the potential failure modes, so the practice of the USACE EIS contractor (AECOM) previously selecting the scenarios prior to the workshop is problematic and significantly compromises the FMEA. In addition, the report does not identify the workshop participants and expert panel or their qualifications. Based on previous practice with other projects the participants are identified and asked to review and sign-off on any workshop results presented to the public as consensus results. This deviation from accepted practice constitutes a significant fatal flaw in with the DEIS.

Finally, it is unclear how an actual participant in the workshop can act as a "third-party reviewer." The use of a FMEA in the DEIS process is laudable, however, the manner in which the FMEA is being used is less than optimal and in fact is misleading. This deficiency could be corrected by ensuring that tribal and public stakeholder experts are involved in the analysis, allowing it to be robust, and making it completely transparent.

According to the DEIS: "*In accordance with NEPA guidelines, failure scenarios selected for analysis in the EIS were low probability and a comparatively high level of consequence*." (DEIS at 4.27-72). The DEIS should identify the NEPA guidelines that make this suggestion, but in our view this statement is not true. The purpose of a FMEA is risk analysis: Risk = Probability x Consequences.

The table below provides the rationale for why FMEA's must consider a wide range of probabilities and consequences other than those suggested in the DEIS. As the table demonstrates, the risk from a high probability and low consequence failure is equal to that of a low probability and high consequence; therefore, it does not make sense to consider only low probability failures.

Risk Matrix Table

Probability	Consequence	Risk
1	3	3
2	2	4
3	1	3

Probability and Consequence Values
1 = High
2 = Medium
3 = Low
Risk = Probability x Consequences

The DEIS states: "*The probability of a full breach of the bulk or pyritic TSF tailings embankments was assessed to be extremely low (i.e., worst case).*" (DEIS at 4.27-72). Although the DEIS does not state it, this is the apparent reason that a catastrophic breach was not considered in the DEIS. This might be the outcome in a properly conducted FMEA where the analysis of all failure modes was not precluded; however, participants would recognize "that it has and could occur, and therefore should be considered in the FMEA." The USACE should also note that this failure mode has been included in other TSF EISs since 2015, and to not include it constitutes a fatal flaw in the DEIS.

4.27.6.7 Existing Response Capacity

This section implies that in the event of a large-scale release, affected watersheds would be sacrificed, because there is no way to recover and store the tailings and restore the damaged environment. This is accurate and should be more clearly described in the DEIS so that decision makers, and the public know the complete implications of mine development.

The first paragraph of the section describes an Emergency Action Plan (EAP) as required by the ADSP, whereas the remainder of the section describes the challenges related to mitigation of a catastrophic release from a TSF. The DEIS should make clear that the EAP does not include or address mitigation measures but instead is focused on protection of human life and, to a lesser extent, protection of property. The EAP does not address prevention of a catastrophic release but rather a response to a catastrophic release.

It should be understood that the EAP is based on a catastrophic TSF release (or at least should be) in accordance with the Canadian Dam Association (CDA) Dam Safety Guidelines and other guidelines pertaining to tailings dams. While the EAP might also address events such as a pipeline spill, as these events may not result in human safety issues beyond the mine site, their inclusion would not be typical. <u>The requirement for an EAP based on a catastrophic failure further supports our recommendation that the DEIS should evaluate the short-term, long-term and cumulative impacts of this type of failure in detail</u>.

4.27.6.8 Mitigation

<u>Bulk TSF</u>

Bulk TSF Design Features

In describing "*<u>Bulk TSF</u>*" under "*Bulk TSF Design Features*" the DEIS identifies seepage "*through and out of the TSF*" but fails to further describe that it would be captured and either recycled to processing or treated prior to release (including treatment in-perpetuity post-closure). (DEIS at 4.27-74). In doing so, the DEIS also fails to identify and evaluate potential impacts from seepage from the TSFs that is not captured during operations or post-closure. This is considered a typical *environmental failure mode* that is common in FMEAs that are not strictly held to geotechnical considerations and is an example of an additional failure mode that a multi-stakeholder FMEA would be expected to identify and recommend for inclusion in the DEIS.

Also, according to the DEIS: "*At the close of operations, the TSF would remain in place under "dry storage" conditions in perpetuity. The TSF would be drained of excess fluid, and the tailings would be contoured into a permanent landform.*" (DEIS at 4.27-74). The DEIS should provide a detailed description of the time-frame and requirements to achieve a permanent landform, which requires more than just draining the TSF of excess fluid.

Pyritic TSF Design Features
In describing "*Bulk TSF*" under "*Pyritic TSF Design Features*" the DEIS suggests that the "*Synthetic liner would reduce the risk of embankment failure due to seepage and piping*" but does not address liner leakage. (DEIS at 4.27-74). Liner leakage is an almost certain environmental failure mode (e.g. all liners leak) that should be considered and evaluated in the DEIS.

4.27.6.9 Tailings Release Scenarios
According to the DEIS: "*Massive, catastrophic releases that were deemed extremely unlikely were also ruled out for analysis . . .*" (DEIS at 4.27-75). As previously recommended, catastrophic release from a TSF embankment failure should be described and evaluated in the DEIS, and the potential short-, long-term and cumulative impacts should be described and evaluated, since such an event, even if low probability, is still possible. Decision makers and the public affected by the proposed project should be informed of this potential and the associated impacts in the DEIS. In addition, environmental failures impacting water quality should similarly be identified and addressed in the DEIS.

Impacts of a Bulk Tailings Delivery Pipeline Rupture
Soils
Metals Contamination
This section is overly optimistic about the ability to recover soils contaminated with tailings. The various difficulties involved in remediating a remote area such as this are well described above, but here it is simply assumed that all tailings and tailing-impacted soils could be removed, even though they would be present in a thin veneer over 46 acres. The mechanism, including regulatory authority that would require the Applicant to conduct this level of soil remediation, should be clearly described.

This section also misses the point of sediment guidelines by implying that the only impacts would occur from metals leaching out of the tailings. Bulk metals in fine-grained material such as tailings solids mixed with soils are toxic in and of themselves to plants, soil invertebrates, birds, and mammals that may ingest soil or soil-dwelling organisms.

Water and Sediment Quality

Residual Toxins

As with other impacts discussed in this section, the distance downstream before xanthate would be neutralized to a non-toxic form should be estimated.

Sediments

See comment on Soils, Metals Contamination in this section about metals toxicity in bulk soils and sediments. Tailings will be very difficult or impossible to remove from sediments in water bodies and will likely persist indefinitely. Metals do not need to leach out of sediments to be toxic to sediment-dwelling organisms. As with water quality, the distance downstream that sediments would be expected to exceed sediment quality guidelines for various metals should be estimated.

Wetland, Special Aquatic Sites, and Vegetation

The level and significance of impacts to wetlands are expected to be much greater than indicated here. Recovery of plant life would be slowed by metals in the tailings if allowed to remain in the wetlands. Removal of tailings from the wetlands is also likely to have serious impacts on the wetlands due to the use of heavy machinery, excavation, and removal of plant life. Without active restoration, the wetlands would remain impacted for an indefinite period of time.

Fish

This section underestimates the potential impacts to fish, if only from highly elevated TSS and smothering of fish eggs. The DEIS should describe the level of TSS that would be required to cause fish and invertebrate mortality and compare that to the predicted TSS. Depending on the timing, it is probable that much of a year's productivity could be lost. In addition, potentially permanent habitat alterations could result in loss of suitable spawning, rearing and over-wintering areas for many years. The DEIS should fully describe and evaluate these potential impacts to fish and fish habitat associated with the proposed project.

Commercial and Recreational Fishing

A large release from the proposed Pebble Project of any kind would likely have a much greater impact on the desirability of the area for subsistence, recreational and commercial fishing than would be indicated by the relative impacted acreage alone. The attraction of this area to fishermen is largely in its pristine nature, the perception (and reality) of which would be

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dramatically altered by such an event, potentially affecting a much larger area surrounding the actual spill site. The DEIS should evaluate the potential impacts to the entire area affected by a large release from the proposed project.

Scenario: Pyritic Tailings South Embankment Release into the SFK

As with the bulk tailings release scenario, this selected scenario should be put into context for the reader among all the possible release scenarios for the pyritic tailings.

A scenario should be developed for a massive catastrophic TSF from the Pyritic Tailings impoundment into the South Fork Koktuli (SFK). Such a large failure would most likely occur in the long term; therefore, a series of scenarios should be developed for less TSF failure in the near term. These scenarios and the evaluation of the potential impacts from each scenario should be included in a revised DEIS. The revised DEIS should be released to cooperating agencies and the public for review and comment.

Impacts of a Pyritic Tailings South Embankment Release into the SFK

Many of our previous comments provided on the above scenario are equally applicable to this scenario, specifically those relating to effects on soil and sediment quality, wetlands, fish mortality, subsistence, and recreational uses. However, impacts in this scenario would be expected to be much greater, due to the initial habitat-altering force of the release and the higher toxicity of the pyritic tailings. It would be virtually impossible to remove the tailings from the streams indicates that metals toxicity will persist much longer than a few weeks and would realistically continue to impact these watersheds in perpetuity. This observation is consistent with the long-term impacts observed in other areas and watersheds affected by metal mining and processing.

4.27.7 Untreated Contact Water Release

The DEIS states, "The magnitude of the impact of an untreated contact water release would depend on many factors, as described above. For small releases, downstream dilution would minimize potential impacts due to constituent contamination. In the event of a large volume or a persistent ongoing release, however, the elevated metals could cause a more intense impact." (DEIS at 4.27-114). This and any statement like it should supported with specific estimates of dilution as a mitigation measure, particularly for large-magnitude releases. The dilution estimates should be applied to determine whether water quality standards would be exceeded and if so, what uses would be impaired.

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4.27.7.9 Impacts of Contact Water Release from the WMP

<u>Fish</u>

The DEIS states that "*Potential impacts to fish from the release of untreated contact water would be similar to those described above for elevated metals impacts from the pyritic release scenario.*" (DEIS at 4.27-124). This statement is an inadequate assessment of impacts to fish and aquatic resources, the resources most likely to be impacted by this scenario. The release of contact water for the WMP is also likely to impact a variety of other wildlife and humans that ingest fish.

The described release would occur over a period of a month, which greatly exceeds both acute and chronic water quality criteria timeframes, and in this respect is quite different from the other scenarios evaluated. <u>The DEIS should include a full assessment of risks to fish and aquatic invertebrates under this release scenario.</u>

<u>The DEIS should include an objective and thorough evaluation of the potential short-term, long-term, and cumulative impacts of contact water releases from the WMP</u>.

<u>Conclusions and Recommendations</u>

Our review of the DEIS with respect to potential catastrophic failures and spills resulted in the following conclusions and recommendations:

- The Ridolfi FMEA workshop participants, acting on behalf of the Nondalton Tribal Council, concluded that the Pebble FMEA workshop provided results that are biased to support a pre-determined decision not to include a full breach analysis in the DEIS.
- The results of the Pebble FMEA are also biased in terms of underestimating both probabilities and consequences of all potential failure modes (PFMs).
- <u>To ensure that the DEIS provides a hard look at potential consequences, the Ridolfi FMEA workshop participants, acting on behalf of </u>the Nondalton Tribal Council <u>recommend that the DEIS be supplemented with information from a modified and revised FMEA derived from a workshop involving representatives of all stakeholders and well-qualified and experienced experts.</u> Ridolfi expects that such an approach would result in a more balanced approach to assessing potential failure modes and determining which failures should be analyzed in the DEIS.
- The DEIS is incomplete, inadequate, and deficient and does not comply with NEPA requirements.

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RIDOLFI
Environmental

Critical Review of the Pebble Project Environmental Impact Statement Phase

Failure Modes and Effects Analysis (FMEA) and Alternative FMEA Workshop Report Technical Memorandum No. 4, Attachment 4A

APRIL 2019

Technical Memorandum No. 4 Attachment 4A

Critical Review of the Pebble Project Environmental Impact Statement-Phase Failure Modes and Effects Analysis (FMEA) and Alternative FMEA Workshop Report
Seattle, Washington

Prepared for
Native American Rights Fund
on behalf of

Nondalton Tribal Council and
United Tribes of Bristol Bay

Prepared by
RIDOLFI Inc.

April 2019

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LIST OF ABBREVIATIONS AND ACRONYMS

AECOM	Environmental Impact Statement Contractor
ADEC	Alaska Department of Environmental Conservation
ADSP	Alaska Dam Safety Program
ADNR	Alaska Department of Natural Resources
AP	Accredited Professional
EIS	Environmental Impact Statement
EoR	Engineer of Record
FERC	Federal Energy Regulatory Commission
FMEA	Failure Modes and Effects Analysis
ICOLD	International Commission on Large Dams
IERP	Independent Expert Review Panel
L.G.	Liscenced Geologist
LEED	Leadership in Energy and Environmental Design
M.S.	Master of Science
NARF	Native American Rights Fund
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
P.E.	Professional Engineer
PAG	Potentially acid-generating
PDEIS	Preliminary Draft Environmental Impact Statement
PFM	Potential Failure Modes

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PLP	Pebble Limited Partnership
Ridolfi	RIDOLFI Environmental, Inc.
SRK	SRK Consulting
TSF	Tailings Storage Facilities
USACE	United States Army Corps of Engineers
WMP	Water Management Ponds

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1.0 INTRODUCTION

RIDOLFI Environmental (Ridolfi) on behalf of the Native American Rights Fund (NARF) has reviewed the Pebble Environmental Impact Statement (EIS)-Phase Failure Modes and Effects Analysis Workshop Report (Pebble FMEA Report) dated December 2018. According to the Pebble FMEA Report:

On October 24-25 of 2018, the U.S. Army Corps of Engineers (USACE) and AECOM hosted an EIS-Phase Failure Modes and Effects Analysis (EIS-Phase FMEA) workshop to develop embankment failure scenarios to be analyzed in the EIS. The FMEA workshop was conducted by a facilitator with a panel of experts who analyzed the potential likelihoods and environmental consequences of a broad range of embankment failures. FMEAs are widely used as a risk management tool across various industries. FMEA products include a list of potential failure modes (PFMs) and a determination of likelihoods and effects severity (consequences) for each failure mode. As pertains to dam failures, the FMEA process can be used to strengthen engineering design, inform subsequent stages of site investigation, and provide input for the dam permitting process.

The introduction to the Pebble FMEA Report notes that the current Pebble Project embankment designs are at an early-phase conceptual level with geotechnical investigations yet to be performed at the major embankment sites. This current conceptual design level inherently results in high levels of uncertainty; therefore, the panel relied on design criteria that would be implemented rather than on actual design analysis. The report identifies design criteria of the Alaska Dam Safety Program (ADSP) guidelines, while at the same time the report qualifies the effort as an EIS-Phase FMEA for EIS/National Environmental Policy Act (NEPA) purposes and not to satisfy Alaska Department of Natural Resources (ADNR) permit approval requirements. This suggests that "Pebble Limited Partnership (PLP) and its engineering consultants Knight Piésold would be required to provide additional technical risk assessment well beyond the scope of the FMEA" prior to approval of dam construction.

The following comments provide a critique of the Pebble FMEA Report and question the validity of the results and their application to the EIS/NEPA process for the proposed Pebble Project. Ridolfi conducted a workshop that resulted in a different outcome reflective of additional stakeholder input. This outcome and rationale to support an alternative FMEA are discussed in this report.

2.0 OBJECTIVE

According to the Pebble FMEA Report:

The objective of the EIS-Phase FMEA was to determine reasonable dam failure scenarios and associated volumes of release to be modeled and analyzed for impacts in the EIS. The term "failure" relates to unintended release of the impounded material(s) and *can be either a partial release or full breach of the embankment. In accordance with NEPA guidelines, failure scenarios selected for analysis in the EIS should have a low level of probability, and a comparatively high level of consequence. Minor failures that result in small releases have a relatively high probability of occurrence, but typically have low environmental impacts. Moreover, NEPA analysis does not benefit from evaluation of spill scenarios, whether small, moderate, large or worst-case, that are so remotely improbable that the risk presented is negligible.*

The EIS-Phase FMEA considered PFMs with a broad range of probabilities and consequences. The expert panel then identified those PFMs that had a low probability of occurrence, and comparatively high level of consequence. The definition of "low probability" as applied during the workshop was: "The possibility cannot be ruled out, but there is no compelling evidence to suggest it is conceivable under anything but extreme circumstances."

Comments: The report focuses on the definition and identification of "low probability" potential failure modes (PFMs) suggesting that such events, because they are inconceivable under anything but extreme circumstances, are so remotely improbable that the risk presented is negligible, however, participants in the Ridolfi workshop noted that TSF failures occur for other than extreme circumstances, including from systemic failures, none of which on its own could be characterized as "extreme circumstances," yet when occurring together result in a failure. Likewise, the participants in the Ridolfi workshop noted that given the present prevalence and magnitude of TSF failures worldwide, the circumstances leading to failures occurring cannot be considered "remotely improbable" and regardless, given the significant loss of human life caused by the collapse of Vale's Brumadinho tailings dam in Brazil and other failures, the risk cannot be considered "negligible." The Ridolfi workshop participants concluded that "There is no compelling evidence to suggest TSF failures are conceivable under only extreme circumstances" and thereby took exception to the underlying premise of the Pebble FMEA Report.

According to the Pebble FMEA report, the FMEA was used to select PFMs for inclusion in the EIS. Only the selected scenarios included in the EIS were modeled for inundation to determine downstream extent of potential impacts from released tailings solids and fluids. The Pebble FMEA Report workshop participants were not provided with or informed by inundation maps of all PFMs, including those for full breach scenarios. Thus, the participants were not provided a valuable tool that would aid them in understanding and more accurately evaluating the potential severity of full-breach scenarios. The Ridolfi workshop participants had the benefit of a full-breach inundation analysis as discussed below, and this provided them a better understanding and ability to evaluate the consequences and severity of a full breach in an unbiased manner.

Furthermore, according to the Pebble FMEA Report, the workshop was conducted October 24-25, 2018 and used to select scenarios in the EIS to determine downstream extent of potential impacts from released tailings solids and fluids. Unless the impact analyses in the EIS was delayed until following the workshop, which was not evident to reviewers of the Preliminary Draft EIS (PDEIS), it would appear the Pebble FMEA Report was prepared to justify a pre-determined selection of scenarios by the EIS contractor (AECOM).

The EIS-phase FMEA workshop should be performed again with inundation analysis for all PFMs and reconsideration of "negligible" low-probability events. Once this is done, the draft EIS should be revised to include this more thorough analysis and reflect the corrected results.

3.0 WORKSHOP PARTICIPANTS

The Pebble FMEA Report workshop was facilitated by Jennifer Williams, P.E., of AECOM. According to the report "*Ms. Williams is a geotechnical engineer with more than 20 years of experience, focused primarily on dam safety assessments, potential failure mode analysis, and risk analyses.*" The workshop included 15 participants: USACE (2); ADNR (1); PLP (2), KP (2), and AECOM (8).

By contrast, the Donlin Gold Early Stage FMEA workshop, conducted in December 2014 in advance of the Draft EIS, was facilitated by Daryl Hockley, P.E., a civil engineer with over 25 years of experience including facilitation of FMEA workshops for tailings facilities at other mines in Alaska, northern Canada, and overseas. The Donlin Gold FMEA workshop included 24 participants representing each entity as follows: USACE (0); ADNR (3); Donlin Gold/Barrick/Novagold (4); BGC (5); AECOM/URS (3); Geosyntec (1); Tetra Tech (1); Alaska Department of Environmental Conservation (ADEC) (1); SRK (4); Calista (1); and TKC (1).

The Ridolfi FMEA workshop, conducted in March 2019, was facilitated by Jim Kuipers, P.E., a mining and mineral processing engineer with over 35 years of experience including TSF design, construction, operation, and closure and participation in and facilitation of FMEA workshops for tailings facilities at other mines in the U.S. and Canada. Kuipers is the principal of Kuipers & Associates and a consultant to Ridolfi Environmental. The Ridolfi FMEA workshop included four other participants who are employees of Ridolfi:

- Bruno Ridolfi, P.E., Principal Engineer, mining and waste management
- Tom Bowden, L.G., Principal Geologist, environmental science and natural resources management
- Bill Beckley, M.S., Principal Scientist, Environmental policy, regulatory analysis, and management
- Callie Ridolfi, P.E., LEED AP, Principal Engineer, environmental engineering, natural resources management, and sustainable systems analysis

Comments: Of the 15 participants in the Pebble FMEA workshop, 10 represented either the lead agency (USACE) or the EIS contractor (AECOM). There were two participants representing the project proponents, PLP. The Engineer of Record (EoR), Knight Piesold, was represented by two participants. One representative from Alaska Department of Natural Resources (ADNR) participated. There were no representatives from other state or federal agencies, no other consultants, and no stakeholder representatives including landowner representatives. In contrast to the Donlin Gold Early-Stage FMEA workshop the Pebble FMEA workshop was heavily weighted towards participation by the lead agency and EIS contractor, involved only limited participants on behalf of the EoR or ADNR, with no other consultants, stakeholder representatives, or landowner representatives.

The Donlin Gold Early-Stage FMEA serves as an example of how the Pebble FMEA workshop could have been performed in a less-biased manner. The Pebble FMEA workshop should be performed again, and the Draft EIS (DEIS) should be revised to include new information and reflect the results of a thorough FMEA works. The Donlin Gold Early-Stage FMEA involved limited participation by the lead agency and EIS contractor. It included four State agency representatives, several technical consultants, and two landowner representatives. Based on our experience, and consistent with FMEA guidance, the process should be further improved by including qualified participants on behalf of each stakeholder including cooperating agencies and indigenous communities.

The Ridolfi FMEA workshop was performed to demonstrate what a small but qualified and diverse group of engineers and scientists representing one of the cooperating agencies might otherwise have provided as input had they participated in the Pebble FMEA Report workshop.

4.0 SCOPE

The Pebble FMEA Report workshop focused on the failure of four major embankments associated with the Tailings Storage Facilities (TSFs) and Water Management Pond (WMP):

- Bulk TSF main embankment
- Pyritic TSF north embankment
- Pyritic TSF south embankment
- Main WMP embankment

Comments: The Pebble FMEA Report did not include potential failure modes and effects for other potential areas of risk outside of the TSFs and Main WMP. The report does not explain why the workshop focused on only failure modes associated with the four embankments, since other failure modes could lead to critical failure scenarios. Other potential failure modes include pipeline, barge, and other transportation failures due to a variety of causes leading to the release and spills of concentrates, chemicals, and other contaminants into surface water and groundwater potentially harming biota including fish, wildlife, and humans.

5.0 POTENTIAL FAILURE MODE IDENTIFICATION

The Pebble FMEA Report workshop was conducted using a pre-populated list of PFMs for each facility. As noted in the report, "*The focus of the EIS-Phase FMEA was on the construction and 20-year operational timeframe.*" The list assumed the Pyritic TSF and Main WMP embankments would be removed at the close of operations, and the pyritic tailings and PAG waste rock would be backfilled into the open pit; therefore, those facilities were not evaluated for the post-closure time frame. Also, according to the report, "*The Bulk TSF embankment would remain in place indefinitely, with the bulk tailings in dry closure. The post-closure timeframe was therefore considered in the analysis for the Bulk TSF.*"

The Pebble FMEA Report pre-populated list of PFMs (Report Table 1: Initial List of Potential Failure Modes) can be summarized as follows:

Bulk TSF Main Embankment

Project Phase	Condition	Type of Breach	PFMs
Construction/Operation	Normal	Partial Release	16
Construction/Operation	Normal	Full Breach	1
Construction/Operation	Flood	Partial Release	2
Construction/Operation	Flood	Full Breach	0
Construction/Operation	Earthquake	Partial Release	3
Construction/Operation	Earthquake	Full Breach	0
Closure	-	-	*No PFMs (Assumed removed at closure)

Pyritic TSF Embankments

Project Phase	Condition	Type of Breach	PFMs
Construction/Operation	Normal	Partial Release	14
Construction/Operation	Normal	Full Breach	0
Construction/Operation	Flood	Partial Release	1
Construction/Operation	Flood	Full Breach	0
Construction/Operation	Earthquake	Partial Release	2
Construction/Operation	Earthquake	Full Breach	0
Closure	-	-	*No PFMs (Assumed removed at closure)

Main Water Management Pond Embankment

Project Phase	Condition	Type of Breach	PFMs
Construction/Operation	Normal	Partial Release	14
Construction/Operation	Normal	Full Breach	1
Construction/Operation	Flood	Partial Release	2
Construction/Operation	Flood	Full Breach	0
Construction/Operation	Earthquake	Partial Release	2
Construction/Operation	Earthquake	Full Breach	0
Closure	-	-	*No PFMs (Assumed removed at closure)

The initial list of PFMs was heavily biased towards partial release scenarios and did not include closure and post-closure scenarios. In describing the only PFM involving a Full Breach of the Bulk TSF Main Embankment, the Pebble FMEA Report described the failure mode as "*Internal erosion due to inadequate compaction and voids in embankment fill leading to full dam breach due to unsuccessful detention and intervention*" but then "*Ruled out as Remote during the 20-year operational life due to likelihood of successful detection and intervention.*" Conversely, the only PFM involving a Full Breach of the Main WMP Embankment in the Pebble FMEA Report described the failure mode as "*Slope stability failure resulting from different foundation condition than characterized leading to crest deformation and overflow of tailings causing downcutting of embankment and full dam breach.*"

The final list of PFMs as contained in the PFM Registries in the Pebble FMEA Report can be summarized as follows:

Bulk TSF Main Embankment

Project Phase	Condition	Evaluation Status	Type of Breach	PFMs
Construction/Operation	Normal	Ruled Out	-	3
Construction/Operation	Normal	Evaluated	Partial Release	10
Construction/Operation	Normal	Evaluated	Dam Breach	8
Construction/Operation	Flood	Ruled Out	-	1
Construction/Operation	Flood	Evaluated	Partial Release	2
Construction/Operation	Flood	Evaluated	Dam Breach	1
Construction/Operation	Earthquake	Ruled Out	-	1
Construction/Operation	Earthquake	Evaluated	Partial Release	2
Construction/Operation	Earthquake	Evaluated	Dam Breach	1
Post-Closure Conditions	Post-Closure	Ruled Out	-	2
Post-Closure Conditions	Post-Closure	Evaluated	Partial Release	3
Post-Closure Conditions	Post-Closure	Evaluated	Dam Breach	1

Pyritic TSF Embankments – North Embankment

Project Phase	Condition	Evaluation Status	Type of Breach	PFMs
Construction/Operation	Normal	Ruled Out	-	8
Construction/Operation	Normal	Evaluated	Partial Release	5
Construction/Operation	Normal	Evaluated	Dam Breach	6
Construction/Operation	Flood	Ruled Out	-	0
Construction/Operation	Flood	Evaluated	Partial Release	0
Construction/Operation	Flood	Evaluated	Dam Breach	3
Construction/Operation	Earthquake	Ruled Out	-	0
Construction/Operation	Earthquake	Evaluated	Partial Release	4
Construction/Operation	Earthquake	Evaluated	Dam Breach	1
Closure	-	-	-	*No PFMs (Assumed removed at closure)

Pyritic TSF Embankments – South Embankment

Project Phase	Condition	Evaluation Status	Type of Breach	PFMs
Construction/Operation	Normal	Ruled Out	-	8
Construction/Operation	Normal	Evaluated	Partial Release	5
Construction/Operation	Normal	Evaluated	Dam Breach	6
Construction/Operation	Flood	Ruled Out	-	0
Construction/Operation	Flood	Evaluated	Partial Release	0
Construction/Operation	Flood	Evaluated	Dam Breach	3
Construction/Operation	Earthquake	Ruled Out	-	0
Construction/Operation	Earthquake	Evaluated	Partial Release	4
Construction/Operation	Earthquake	Evaluated	Dam Breach	1
Closure	-	-	-	*No PFMs (Assumed removed at closure)

Main Water Management Pond Embankment

Project Phase	Condition	Evaluation Status	Type of Breach	PFMs
Construction/Operation	Normal	Ruled Out	-	5
Construction/Operation	Normal	Evaluated	Partial Release	7
Construction/Operation	Normal	Evaluated	Dam Breach	8
Construction/Operation	Flood	Ruled Out	-	0
Construction/Operation	Flood	Evaluated	Partial Release	2
Construction/Operation	Flood	Evaluated	Dam Breach	4
Construction/Operation	Earthquake	Ruled Out	-	0
Construction/Operation	Earthquake	Evaluated	Partial Release	4
Construction/Operation	Earthquake	Evaluated	Dam Breach	1
Closure	-	-	-	*No PFMs (Assumed removed at closure)

Comments: The Pebble FMEA Report does not describe the discussions or rationale that led to the changes from the initial list of PFMs to the final list of PFMs. Notably, the final list included additional PFMs that resulted in a Dam Breach, like a Full Breach identified in the initial list. In addition, the final list of PFMs for the Bulk TSF Main Embankment included six PFMs for post-closure conditions, two of which were ruled out, and four were evaluated including one for a

Dam Breach. The Draft EIS should be revised to include a summary of the discussions and rationale that led to the expanded and revised list of PFMs.

The Ridolfi FMEA workshop participants identified three problematic aspects of the Pebble FMEA Report. First, the analysis for the Pyritic TSF assumes all PAG waste rock and pyritic tailings will be removed and backfilled in the open pit. The likelihood of backfilling the pit after about 10 percent of the measured ore reserves are mined is very low, since this would close access to the remaining 90 percent of the ore body, which is generally of higher grade. This has been discussed in previous comments concerning the proposed project's economic feasibility, which would, if the proposed project is permitted and proceeds, rely heavily on expansion and additional future mining beyond the initial open pit. Expansion and future mining beyond the initial open pit are highly probable and backfilling the pit with PAG waste rock and pyritic tailings would preclude future mining by stranding or sterilizing a substantial portion of the measured reserves. Based on this high probability of expansion and future mining, the Draft EIS and Pebble FMEA Report should be revised to include scenarios that result in leaving the pyritic TSF in place at closure, identifies potential impacts, evaluates these impacts, and proposes mitigation measures for each scenario.

Second, while the final list of PFMs did include post-closure scenarios for the Bulk TSF Main Embankment, the project proponent has not provided a sufficiently detailed reclamation and closure plan with information that allows for an understanding of the site conditions, particularly with respect to the Bulk TSF, that will be achieved post-closure. It appears the TSF design will result in areas of the TSF that are highly saturated while other areas are relied upon to naturally drain. These conditions are not consistent with the description of "dry closure" and do not consider future conditions that might result, such as plugging of the drainage features of the main embankment. The Ridolfi FMEA workshop participants noted that the initial permit application materials did not contain a reclamation and closure plan, and that the project proponent did not provide a plan in response to a request for additional information from the EIS contractor (AECOM).

Third, if the proposed Pebble Project is permitted, constructed, and operated, the TSFs would result in significant risks of failure and environmental impacts during the foreseeable future and beyond. The long-term risks would persist for hundreds or thousands of years, which is way beyond the focus of the Pebble FMEA that was based on a comparatively short construction period and a 20-year operational timeframe. The PFMs for the proposed project need to consider long-term design considerations and impacts from expanded operations beyond the

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20-year time frame. The 78-year time frame considered in the Draft EIS analysis of cumulative impacts should be the basis for FMEA that includes long-term operations, closure activities, and long-term treatment, monitoring, and maintenance of the TSFs.

Additional comments on specific PFMs from the Ridolfi FMEA workshop are included in following sections.

6.0 FMEA METHODOLOGY

According to the Pebble FMEA Report:

The FMEA used a semi-quantitative methodology to examine the probability and consequences of failure scenarios for EIS purposes. Workshop participants evaluated the identified PFMs based on a likelihood and consequence ranking framework. Risk rating methods were expert-based, rather than analytical. Assessments of consequence severity and likelihood were based on the consensus of expert opinion, rather than on calculations of probabilities. Subjective estimating was used in a team setting so that the discussion enhanced and drew out the breadth of experience by the group of individuals qualified to make the estimates.

The Pebble FMEA workshop participants were provided a table of assigned failure likelihood categories based on proposed descriptors (Pebble FMEA Report Table 2). The report makes two distinctions when assigning likelihood to the PFMs:

- *The likelihood of failure is a function of both the likelihood of the loading condition that could lead to failure, and the likelihood of failure given the loading condition. For normal operating conditions, the likelihood of the loading is high. However, for floods or earthquakes, the likelihood of the loading could be small. Therefore, both the likelihood of the loading and the likelihood of failure were considered in the likelihood estimation.*

- *In ranking the failure likelihood for the PFMs, the panel assumed that design criteria in accordance with ADSP guidelines would be followed, including but not limited to: compliance with construction plans, specifications and design intent; stringent quality control and quality assurance procedures during construction; placement of ballast rock and other protective layer on top of liners; pervious/free draining embankment rock fill; adequate freeboard in TSFs for each raise during operations; open channel spillway at final embankment configurations, capture and return of all seepage that may flow through, under or around all embankments; etc. It was assumed that design and construction plans, specifications, quality assurance plan, operations and maintenance manual, and emergency action plan would all meet safety regulations for Class I dams, as per ADSP guidelines and the standards and procedures referenced in the guidelines.*

After assigning likelihood to PFMs, workshop participants assigned a level of consequence severity for Human Health and Safety and Environmental Impact and Land Use based on a table of consequence descriptors (Pebble FMEA Report Table 3). The Pebble FMEA report noted that the EIS-Phase FMEA did not consider financial impacts to PLP.

Comments: Conducting FMEAs for TSFs is considered current industry best practice and likewise is considered best practice for aspects of the NEPA processe such as an EIS for a mining project. The Pebble FMEA workshop participants were referred to Robertson and Shaw (2003) to describe FMEA practice for mine facilities, and similarly the Pebble FMEA Report failure likelihood and consequence categories and severity descriptors appear, with some specific exceptions, to mirror those used by Robertson and Shaw; however, the Pebble FMEA Report does not reflect categories and descriptors that have since been modified and are currently in common use both in the U.S. and Canada. These modified descriptors were used for similar purposes in the Donlin Gold Project Early-Stage FMEA, which is discussed further below.

In using Robertson and Shaw (2003) as the basis for the Pebble FMEA workshop, some specific exceptions were made by the facilitator and participants. The first is that Robertson and Shaw provides separate descriptors in terms of annualized chance of occurrence for likelihood relative to Safety Consequences and Environmental and Public Concern Consequences. In other words, Robertson and Shaw recommended that different likelihoods would be applied to different consequences descriptors. Rather than conforming to this guidance, the Pebble FMEA workshop applied separate descriptors in terms of annualized chance of occurrence for breach and non-breach scenarios. This is not consistent with the methodology recommended by Robertson and Shaw.

Second, with respect to the severity of effects Robertson and Shaw recommend four categories:

- Biological Impacts and Land Use
- Regulator Impacts and Censure
- Public Concern and Image
- Health and Safety

The Pebble FMEA workshop reduced these four categories to two categories:

- Safety
- Environmental and Public Concern Consequences

The Pebble FMEA workshop did not recognize regulatory impacts and censure or land use and combined environmental and public concern consequences.

Finally, for reasons not explained in the Pebble FMEA Report, the Pebble FMEA workshop altered the descriptors for health and safety related to fatalities. Table A shows the consequence severity descriptors for Health and Safety from Robertson and Shaw (2003), and the Pebble FMEA Report. As indicated by the underlined text in Table A, Robertson and Shaw describes both a single fatality and multiple fatalities as extreme; however, the Pebble FMEA Report describes a single fatality as major, and only multiple fatalities as extreme. Since this alteration both tends to underscore the severity of a single fatality and results in potential underestimation of the potential severity of human health and safety consequences, the Ridolfi FMEA workshop participants identified this change as a highly problematic and unacceptable with respect to the standard of practice of FMEAs The Ridolfi FMEA workshop participants noted that while a similar alteration was made for the Donlin Gold Early-Stage FMEA, this change has not been incorporated in FMEAs being conducted for most other sites in the U.S. and Canada.

The Pebble FMEA Report used an altered risk matrix that deviates from the standard of practice in terms of portraying and interpreting the results. Robertson and Shaw (2003) recommended the risk matrix shown in Figure 1. Subsequently, the risk matrix in common use by TSF FMEA practitioners, including the Donlin Gold Early-Stage FMEA, has been modified to that shown in Figure 2. The altered Pebble FMEA Report risk matrix is shown in Figure 3.

As shown by contrasting Figure 2 representing current practice and Figure 3 representing the Pebble FMEA approach, the Pebble FMEA Report shows low risk associated with moderate/possible likelihood and minor consequences, whereas the standard of practice would be to identify the risk as moderate given the same likelihood and consequence severity. Similarly, the Pebble FMEA Report shows low risk associated with low likelihood and moderate consequences, and very low likelihood and major consequences, whereas the standard of practice would be to identify the risks as moderate in both cases given the same likelihood and consequence severity. Additionally, the Pebble FMEA report indicates moderate to moderately high risk for moderate likelihood and major consequences, whereas the standard of practice would be to identify the risks as high or very high given the same likelihood and consequence severity. The net effect of these specific changes made to the Pebble FMEA risk matrix as compared to standard practice is to understate the potential risk.

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Table A - Human Health and Safety Severity Descriptors

Source	Consequence Categories				
	Negligible	**Low/Minor**	**Moderate**	**High/Major**	**Extreme/Critical**
Robertson and Shaw (2003)	No local/ international/ NGO attention.	First aid required; or small risk of serious injury.	Lost time or injury likely: or some potential for serious injuries; or small risk of fatality	Severe injury or disability likely: or some potential for fatality.	Fatality or multiple fatalities expected.
Pebble FMEA (2018)	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability/ impairment and/or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Single fatality and/or severe irreversible disability or impairment to one or more people.	Multiple fatalities expected.

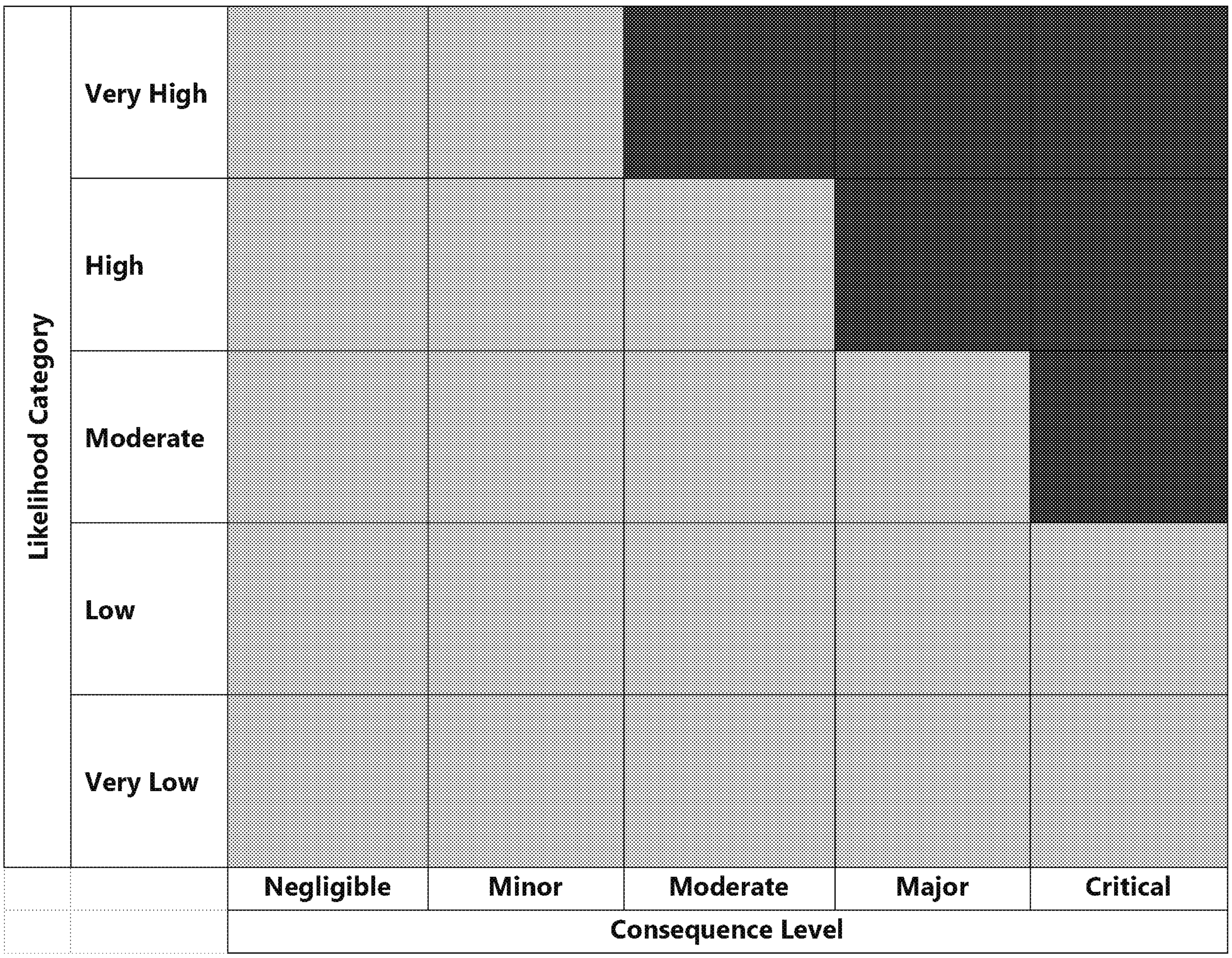
Figure 1. Robertson and Shaw (2003) Example Risk Matrix

		Likelihood				
		Not Likely	**Low**	**Moderate**	**High**	**Expected**
Consequence	**Extreme**	B14.1,B15.2, B16.2	A42.2, A57, A81.6, B14.1, B14.2, B15.2, B13.2, B91.2, B91.3	A81.2, B92.3,B93.2, B93.3	A56, B15.1, B16.1, B91.1	
	High		A101.3	A12.3, A63.3, B11.2, B11.3, B13.1, B13.2	B11.1	B81.1
	Moderate	B17	B17, B92.1, B92.2, B93.1	A63.3, B12.1, B18	A634, B12.2, B55.2	B81.3, B81.4, B94.1, B94.2
	Low		A13, A22.2, A61.5, A92.2, A92.5, B85	A101.4	A53.2, A55.2, A61.4, A61.6, A71.1, A71.2, A81.4, A81.5, A92.3	A14.1, A54, A63.1, A63.2, A81.3, A92.1, A92.4, A92.6, B51,B52, B53, B71.1, B71.2, B81.2
	Negligible		A41.2, A41.4, A41.7, A42.4, A61.1, A63.5, A101.2, A101.6, B21.1, B22.1, B23.1, B31.2, B31.3, B31.4, B31.5, B31.6, B33.4, B33.5, B33.6, B34.1, B37.1, B41.1, B41.2, B41.3, B41.4	A21.1, A21.2, A22.1, A41.5, A41.6, A52, A61.2, A62, A81.1, B31.1, B32.2, B33.1, B36.1	A12.2, A41.1, A41.3, A53.1, A55.1, B31.3, B33.2, B33.3	A11, A12.1, A14.2, A41.8, A42.1, A61.3, A91, A101.5, A101.7, B21.2, B22.2, B23.3, B32.1, B34.2, B35.1, B35.2, B36.2, B37.2

Figure 2. Current Practice FMEA Risk Matrix (from Donlin Gold Early Stage FMEA)

Likelihood	Consequence Severity				
	Very Low	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain	Moderate	Moderately High	High	Very High	Very High
Likely	Moderate	Moderate	Moderately High	High	Very High
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High

Figure 3. Pebble FMEA Report



The effect of the approach reflected in the Pebble FMEA Report risk matrix and the effect of the approach prescribed in the more common standard of practice shown in the FMEA risk matrix is demonstrated in Figure 4. This risk matrix is for the Bulk TSF Main Embankment from the Pebble FMEA Report as compared to Figure 5 showing the same results applied to a standard FMEA risk matrix. Use of the Pebble FMEA Report risk matrix (Figure 4) resulted in all PFMs falling in low overall risk zones, whereas using a standard FMEA risk matrix (Figure 5) resulted in several PFMs in a higher risk zone, as indicated in red type. This suggests moderate, rather than low or negligible risk.

Additionally, the results of the Pebble FMEA were used to justify including PFM #21 in the EIS for analysis. Based on the placement of 21E in the Pebble FMEA Report risk matrix and more particularly in the standard FMEA risk matrix (Figure 5), the results suggest that at least PFM #4 should have been included in the EIS for analysis, and that PMFs #6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 20 also warranted consideration and analysis in the EIS.

The effect of the approach used to alter and populate the Pebble FMEA Report risk matrix as opposed to the more common standard of practice for FMEA risk matrix is further demonstrated in Figure 6, which shows the risk matrix for the Pyritic TSF South Embankment from the Pebble FMEA Report. Figure 7 shows the same results applied to a standard FMEA risk matrix for comparison with the results in Figure 6.

Using the Pebble FMEA Report risk matrix (Figure 6) resulted in many PFMs falling into zone of moderate overall risk, whereas using the standard FMEA risk matrix (Figure 7) resulted in a much greater number of PFMs in a higher risk zone, as indicated in red text. This suggests that the risks are, in some cases, moderate rather than low or negligible.

The results of the Pebble FMEA were used to justify including PFM #1 in the EIS for analysis. Based on the standard FMEA risk matrix (Figure 7), the results suggest that at least PFM #2, 4, and 18 should have also been included in the EIS for analysis, and that PMFs #3, 5, 6, 7, 8, 11, 12, 13, 14, and 16 also warranted consideration and analysis in the EIS.

Figure 4. Bulk TSF Main Embankment - Pebble FMEA Report Risk Matrix

Likelihood Category						
	Very High					
	High					
	Moderate	4H	4E			
	Low	1H, 17H, 18H, 21H	1E, 17E, 18E	21E		
	Very Low	2H, 3H, 5H, 19H	2E, 3E, 5E, 6H, 7H, 15H, 19E		6E, 7E, 8E/H, 9E/H, 10E/H, 11E/H, 12E/H, 13E/H, 14E/H, 15E, 16E/H, 20E/H	
		Negligible	**Minor**	**Moderate**	**Major**	**Critical**
		Consequence Level				

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Figure 5. Bulk TSF Main Embankment - Pebble FMEA Report Using Standard Risk Matrix

Likelihood Category		Negligible	Minor	Moderate	Major	Critical
	Very High					
	High					
	Moderate	4H	4E			
	Low	1H, 17H, 18H, 21H	1E, 17E, 18E	21E		
	Very Low	2H, 3H, 5H, 19H	2E, 3E, 5E, 6H, 7H, 15H, 19E		6E, 7E, 8E/H, 9E/H, 10E/H, 11E/H, 12E/H, 13E/H, 14E/H, 15E, 16E/H, 20E/H	
		Consequence Level				

Numbers in the Matrix refer to corresponding PFM numbers from the first column of the Main WMP Risk Register.

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Figure 6. Pyritic TSF South Embankment - Pebble FMEA Report Risk Matrix

Likelihood Category						
	Very High					
	High					
	Moderate					
	Low	1H, 2H, 4H, 18H		2E, 4E, 18E	1E	
	Very Low	9H, 10H, 15H, 17H, 19H		9E, 10E, 15E, 17E, 19E	3H, 5H, 6H, 7H, 8H, 11H, 12H, 13H, 14H, 16H	3E, 5E, 6E, 7E, 8E, 11E, 12E, 13E, 14E, 16E
		Negligible	**Minor**	**Moderate**	**Major**	**Critical**
		Consequence Level				

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Figure 7. Pyritic TSF South Embankment - Pebble FMEA Report Using Standard Risk Matrix

Likelihood Category		Negligible	Minor	Moderate	Major	Critical
	Very High					
	High					
	Moderate					
	Low	1H, 2H, 4H, 18H		2E, 4E, 18E	1E	
	Very Low	9H, 10H, 15H, 17H, 19H		9E, 10E, 15E, 17E, 19E	3H, 5H, 6H, 7H, 8H, 11H, 12H, 13H, 14H, 16H	3E, 5E, 6E, 7E, 8E, 11E, 12E, 13E, 14E, 16E
		Consequence Level				

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7.0 RIDOLFI FMEA WORKSHOP

This section describes the review process, observations, discussions, determinations, conclusions, and recommendations that resulted from the Ridolfi FMEA workshop.

7.1 Potential Failure Modes

The Ridolfi FMEA workshop participants reviewed the Potential Failure Modes (PFMs) from the Pebble FMEA Report Table 1 and Risk Registers. The participants noted that the descriptions of the PFMs are abbreviated and are not consistent with Federal Energy Regulatory Commission (FERC)[1] and other guidance on the development of PFMs. It is important, regardless of the objective of an FMEA, that the PFMs be adequately described. As noted by FERC, there are three key elements of a PFM description:

- The Initiator (e.g., reservoir load, deterioration/aging operation/systems malfunction, earthquake, flood, etc.)
- The Failure Mechanism/Progression (including location and/or path and a step-by-step progression)
- The Resulting Impact on the Structure (e.g., full or partial failure, rapidity of failure, breach characteristics)

The PFMs in the Pebble FMEA Report lack descriptions of initiators, step-by-step descriptions of the progression of the failure mechanism or mechanisms, and information relative to the definition of full or partial failures, rapidity of the failure, and characteristics of the breach. This information is necessary to understand both the PFMs and the likelihood of the PFMs occurring, as well as the effects.

For example, the Pebble FMEA Report does not describe or define Flood Conditions, Earthquake Conditions, or Post-Closure Conditions. Also, the information provided in the descriptions of effects in most cases should be included in the PFM description. For example, the Pebble FMEA Report describes "Dam Breach" as an effect. In all cases, the dam breach, including information as to magnitude and rapidity of the failure, should be described as the final step in the

1 https://www.ferc.gov/industries/hydropower/safety/initiatives/pfms/pfms.pdf?csrt=10472029686241086l

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description of the PFM. It is important to note whether the failure is assumed to occur progressively or instantaneously, describe what the assumed fill and pool conditions are at the time of the failure, and quantify the volume of tailings solids and supernatant are assumed in the discharge.

7.2 Effects

The Ridolfi FMEA workshop participants reviewed the effects described for each PFM in the Pebble FMEA Report Table 1 and Risk Registers. The participants noted that the descriptions of the effects are abbreviated. The participants also noted that the information provided on effects in most cases belongs in the description of the PFM as noted in the previous section. For example, the effects should provide information on the impacts of a "Dam Breach" such as "resulting in a liquefaction failure instantaneously releasing 30 percent of the combined tailings and supernatant mass in the TSF at full volume and inundating the downstream watershed as indicated by inundation modeling." Without describing and considering this information it would be difficult for FMEA workshop participants to accurately understand and rank the potential effects from a PFM.

The Ridolfi FMEA workshop participants applied hypothetical inundation modeling and GIS mapping contained in Wobus 2019 as the basis for their assessment of effects from a Dam Breach assuming 30-percent tailings slurry release and other conditions as revealed by the modeling. This assessment considered locations of both permanent and seasonal downstream inhabitants. The results of the report showed that under all the scenarios tested, a breach of the Bulk TSF would result in tailings material traveling more than 75 km (approximately 50 miles) downstream beyond the confluence with the Mulchatna River. Over that reach the mudflow would fill the valley bottoms and spread tailings across the off-channel habitat in the floodplains. The tailings mass that would result initially in a mudflow, and eventually settle over the floodplain, would range in depth from less than a meter to over 12 meters and cover an area of approximately 250 square kilometers (km^2).

Within the area of potential tailings inundation there are camps and other traditional use areas, as well as recreational fishing camps. If these camps and use areas are inhabited during a catastrophic failure as depicted, the event could result in loss of human life. Wobus 2019 identified 62 native allotments between the mine site and the Nushagak-Mulchatna River confluence that would be directly affected by a catastrophic TSF failure. Where the modeling was conducted further downstream, 80 percent of the tailings material continues to flow more than 130 kilometers (80 miles) downstream, and 50 percent of the tailings material continues to

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move beyond that reach and would likely reach Bristol Bay. Based on this information, the Ridolfi FMEA workshop participants determined that there was a reasonable likelihood that in the event of a TSF failure, more than one human fatality would occur in the area affected by the event.

7.3 Likelihood

As previously noted in Section 6, the Pebble FMEA Report workshop assignations of likelihood were predicated on:

- The likelihood of failure being a function of both the likelihood of the loading condition that could lead to failure and the likelihood of failure given the loading condition, and
- The Alaska Dam Safety Program (ADSP) providing a high level of assurance as to reduction of likelihood to negligible level.

The Ridolfi FMEA workshop participants were unable to understand the first preposition for other than stability related failures, the logic appears to be circular. The Ridolfi FMEA workshop participants also reviewed the guidance of the ADSP and compared the ADSP guidance to the recommendations of the Mount Polley Independent Expert Review Panel (IERP), Montana's TSF regulations, British Columbia's TSF regulations, and Alaska's TSF regulations. The comparison is provided and discussed in detail in Appendix A and summarized as follows:

- Alaska's dam safety regulations are directed towards water dams and do not reflect the recommendations of the Mount Polley IERP or compare in any way to TSF-specific regulations that have been enacted by Montana and British Columbia in response to the Mount Polley IERP recommendations.
- The ADSP guidelines contain recommendations, but not requirements, for some key elements of the Mount Polley IERP recommendations; however, the ADSP guidelines are incomplete, are not specific to mine TSFs, and are highly subject, in terms of both application and enforcement, to the discretion of the regulator.

Based on our review of the Pebble FMEA Report, the Ridolfi FMEA workshop participants were not able to agree with the use of Very Low and Low likelihoods for nearly all PFMs evaluated in the Pebble FMEA workshop. Based on the Frequency Descriptor 1, it was noted that the PFMs evaluated for dam breach, as well as partial breach or release scenarios, as documented by the International Commission on Large Dams (ICOLD) and other organizations, have in nearly all cases happened elsewhere and could happen in this circumstance in other than extreme situations.

It was also noted that regulatory requirements were not a substitute for strong TSF corporate governance and acceptance of responsibility. The PLP has no demonstrated capacity in this regard. The Ridolfi FMEA workshop participants focused on the PFMs resulting in a dam breach and determined that in all cases their frequency descriptors were consistent with the ranking of Possible. The participants noted that even if the ADSP guidelines were modified to be entirely consistent with Mount Polley IERP recommendations and enacted as regulations, which is strongly recommended, their likelihood ranking would be reduced to Unlikely, suggesting it hasn't happened yet but could, but not very unlikely or conceivable, but only in extreme circumstances. The Mount Polley event demonstrated that a catastrophic failure of a TSF has happened, despite similar safeguards and counter measures. Also, with less than five years' experience with regulations in Montana and British Columbia, it is too soon to say it can't still happen even in those jurisdictions. The Mount Polley IERP report suggests that it will eventually happen if slurry tailings methods are used, it's just a matter of time, and the risk is not negligible.

7.4 Consequence Severity

The Ridolfi FMEA workshop participants reviewed the consequence severity descriptors and categories selected for each PFM in the Pebble FMEA Report Risk Registers, focusing on the PFMs resulting in a dam breach and subsequent effects as described in Section 7.2. The Ridolfi FMEA workshop participants considered the Bulk TSF Main Embankment and Pyritic TSF South Embankment PFMs, Risk Registers, and Risk Matrix results involving dam breach as examples for comparison of the participants opinions of consequence severity and risk based on the information relied upon and described in this report and the results set forth in the Pebble FMEA Report.

Bulk TSF Main Embankment

The Pebble FMEA workshop considered two consequence categories: (1) a combined environmental impact and land use category and (2) a human health and safety category. For the Bulk TSF Main Embankment the Pebble FMEA workshop participants rated the consequences as Major for both categories using the criteria in the Pebble FMEA Report Table 3 including for Health and Safety shown in Table A of this report.

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The description of severity in Pebble FMEA Report Table 3 for the Major human health and safety consequence category is "*Single fatality and/or severe irreversible disability or impairment to one or more people.*" The description in the report for the Major environmental impact and land use category is "*Significant impact on valued ecosystem component and medium-term impairment of ecosystem function. Significant temporary impact to traditional land use with great effort for mitigation.*"

The Ridolfi FMEA workshop participants reviewed the consequence severity descriptors for all six categories in Appendix B Table 1 that, with the exception noted in Table A with respect to human health and safety and fatalities, are similar to those in Pebble FMEA Report Table 3. The Ridolfi FMEA workshop participants determined the following consequences severity descriptors for the six categories to be most accurate based on the consideration of all information that was reviewed and discussed in this report.

1. **Environmental Impact**. Critical. Serious long-term impairment of ecosystem function. The participants noted that where catastrophic TSF failures have occurred and resulted in the impacts that would be expected such as in the case of the Pebble Bulk TSF, restoration efforts at best have only been partially successful and the failures have typically resulted in significant long-term impairment of ecosystem function.

2. **Traditional Use**. Critical. Significant permanent impact on traditional land use. The participants noted that traditional land use is tied to ecosystem function and impacts on the ecosystem would devalue traditional land use. Participants also noted that even if some level of restoration efforts are successfully performed, traditional land use would likely still be impacted due to the stigma of the catastrophe.

3. **Regulatory and Legal**. Critical. Major breach of regulation – willful violation. Court order issued. The participants noted that a catastrophic dam failure in the U.S. would be much more likely to be subject to regulatory, criminal, and civil prosecution than a similar failure anywhere else in the world.

4. **Consequence Costs**. Critical. greater than $10 Million. The participants noted that the cost of cleaning up a catastrophic failure is likely to range from $100 Million to more than $1.0 Billion U.S. dollars.

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5. **Community/Media/Reputation**. Critical. Serious public outcry/demonstrations or adverse international NGO attention or media coverage. The participants noted that given the extraordinary, if not already unprecedented, concerns and opposition to the proposed Pebble Mine, and the recognized unique qualities and values of the Bristol Bay region, not only would a catastrophic TSF failure resulting in a full breach result in serious damage to the mining company's image and reputation, but even a much more limited partial release involving supernatant water would likely result in serious attention from the community and broad media coverage.

6. **Human Health and Safety**. Critical. Single fatality or multiple fatalities. In the event of a TSF failure there is always a risk of fatalities to workers on the site. The participants recognized that in some cases this is described as the "single fatality" scenario and speculated that this might have been the rationale for the Pebble FMEA workshop to have made the changes to the severity matrix identified in Table A. This would have allowed the Pebble FMEA workshop participants to distinguish a single fatality to a worker as of major severity, and fatalities to the public as multiple fatalities resulting in critical severity. The Ridolfi FMEA workshop participants noted that based on the information reviewed, including the inundation analysis, a Bulk TSF Main Embankment dam breach failure would potentially result in fatalities not only to residents at some distance from the mine site, but also to traditional users that might be occupying fishing, hunting, or recreational camps downstream within the watershed.

Pyritic TSF South Embankment

For the Pyritic TSF South Embankment, the Pebble FMEA Report workshop participants rated the consequences as Major for the human health and safety category and Critical for the environmental impact and land use category using the criteria in the Pebble FMEA Report Table 3 including for Health and Safety shown in Table A of this report.

The description of severity in the Pebble FMEA Report Table 3 for the Major human health and safety consequence category is "*Single fatality and/or severe irreversible disability or impairment to one or more people.*" The description in the Pebble FMEA Report for the Critical environmental impact and land use category is "*Serious long-term impairment of ecosystem function. Impact that is widespread and requiring long-term recovery, leaving major residual damage.*"

The Ridolfi FMEA workshop participants reviewed the consequence severity descriptors for the six categories in Appendix B Table 1. The Ridolfi FMEA workshop participants determined that critical consequences severity descriptors for the six categories to be most accurate based on the consideration of all information that was reviewed and discussed in this report and as previously described for the Bulk TSF Main Embankment.

7.5 Risk

The Ridolfi FMEA workshop participants evaluated risk using a standard FMEA risk matrix. The results for the Bulk TSF Main Embankment are shown in Figure 8. Based on a moderate likelihood and critical consequence level, the Ridolfi FMEA workshop participants rated the risk from a dam breach as High (PFMs 6,7,8,9,10,11,12,13,14,15,16, and 20) rather than the Moderate rating or the Low rating determined by the Pebble FMEA workshop participants.

Figure 8. Bulk TSF Main Embankment – Ridolfi FMEA Dam Breach Risk Matrix (Operational Phase)

Likelihood Category	**Very High**					
	High					
	Moderate	4H	4E			6E, 7E, 8E/H, 9E/H, 10E/H, 11E/H, 12E/H, 13E/H, 14E/H, 15E, 16E/H, 20E/H
	Low	1H, 17H, 18H, 21H	1E, 17E, 18E	21E		
	Very Low	2H, 3H, 5H, 19H	2E, 3E, 5E, 6H, 7H, 15H, 19E		~~6E, 7E, 8E/H, 9E/H,10E/H, 11E/H, 12E/H, 13E/H, 14E/H, 15E, 16E/H, 20E/H~~	
		Negligible	**Minor**	**Moderate**	**Major**	**Critical**
		Consequence Level				

The results for the Pyritic TSF South Embankment are shown in Figure 9. Based on a moderate likelihood and critical consequence level, the Ridolfi FMEA workshop participants rated the risk from a dam breach as High (PFMs 3,5,6,7,8,11,12,13,14, and 16) rather than the Moderate rating or Low rating determined by the Pebble FMEA workshop participants.

Figure 9. Pyritic TSF South Embankment – Ridolfi FMEA Dam Breach Risk Matrix (Operational Phase)

Likelihood Category						
Likelihood Category	**Very High**					
Likelihood Category	**High**					
Likelihood Category	**Moderate**					3E/H, 5E/H, 6E/H, 7E/H, 8E/H, 11E/H, 12E/H, 13E/H, 14E/H, 16E/H
Likelihood Category	**Low**	1H, 2H, 4H, 18H		2E, 4E, 18E	1E	
Likelihood Category	**Very Low**	9H, 10H, 15H, 17H, 19H		9E, 10E, 15E, 17E, 19E	~~3H, 5H, 6H, 7H, 8H, 11H, 12H, 13H, 14H, 16H~~	3E, 5E, 6E, 7E, 8E, 11E, ~~12E, 13E, 14E, 16E~~
		Negligible	**Minor**	**Moderate**	**Major**	**Critical**
		Consequence Level				

8.0 CONCLUSIONS AND RECOMMENDATIONS

The Ridolfi FMEA workshop participants concluded that the Pebble FMEA workshop provided results that appear biased to support a decision not to include a full breach analysis in the DEIS.

The results of the Pebble FMEA are also biased in terms of underestimating both likelihoods and consequences of all potential failure modes (PFMs).

To ensure that the EIS provides a hard look at potential consequences, the Ridolfi FMEA workshop participants recommend that the DEIS be revised to include information from a modified and revised FMEA derived from another workshop involving representatives of all stakeholders and well-qualified and experienced experts.

9.0 REFERENCES

Pebble FMEA Report. 2018. Pebble EIS-Phase Failure Modes and Effects Analysis Workshop Report, AECOM for USACE, December 2018. (Pebble DEIS Reference AECOM 2018l)

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Wobus. 2019. A Model Analysis of Flow and Deposition from a Tailings Dam Failure at the Proposed Pebble Mine, Lynker Technologies, LLC, March 12, 2019. https://www.bbrsda.com/reports

Appendix 4A

Comparison of Mount Polley IERP, Montana's TSF regulations, British Columbia's TSF regulations, and Alaska's TSF regulations and guidance.

Comparison of Recommendations of the Mount Polley Independent Expert Review Panel (IERP), Montana's TSF regulations, British Columbia's TSF regulations, and Alaska's TSF regulations

In August 2014, the Mount Polley Mine tailings facility breached, resulting in a catastrophic release of tailings that was previously considered unlikely due to the circumstances of it occurring in what is touted as one of the more progressively regulated jurisdictions (British Columbia - BC) at a mine operated by a rising and supposedly highly capable Canadian based mining company (Imperial Metals) and designed and inspected by leading engineering firms (Knight Piésold and AMEC). The event was considered by the industry and associated engineering consultants as a highly significant event. The need for conservative and proactive measures for the design, operation and closure of tailings facilities has since been further reinforced by the even more catastrophic failure that occurred at the Samarco tailings facility in Brazil in November 2015.

The Mount Polley Independent Expert Review Panel (IERP), consisting of three leading experts in the geotechnical stability of mine tailing facilities, was convened by the BC Government to address the minimization and elimination of the risk of similar failures from tailings facilities. The Panel Report (INDEPENDENT EXPERT ENGINEERING INVESTIGATION AND REVIEW PANEL, REPORT ON MOUNT POLLEY TAILINGS STORAGE FACILITY BREACH (Jan. 30, 2015) [hereafter "Panel Report"]) was issued in January 2015 and included recommendations that can be grouped into the following seven areas:

1. Implement Best Available Practices (BAP) and Best Available Technologies (BAT) using a phased approach,
2. Improve corporate governance,
3. Expand corporate design commitments,
4. Enhance validation of safety and regulation of all phases of a TSF,
5. Strengthen current regulatory operations,
6. Improve professional practice, and
7. Improve dam safety guidelines.

Table 1 summarizes the Panel recommendations and the British Columbia regulatory revisions. For comparison purposes, Table 1 also includes the revisions made to Montana's Metal Mine Reclamation Act (MMRA) in 2015 intended to address the Panel recommendations, and the existing Alaska regulations. The Table also includes information contained in Alaska's 2017 Dam Safety guidelines.

a. Implement Best Available Practices (BAP) and Best Available Technologies (BAT) using a phased approach

The Panel recommended using Best Available Practices (BAP) to address existing TSFs, and recommended using Best Available Technology (BAT). They further recommended applying BAT principles to closure of active impoundments to eliminate risk. The Panel identified the three principles of BAT as: no surface water; unsaturated conditions, and; achieve dilatant conditions by compaction.
The Panel further identified backfilling of mined out pits or underground workings as being the most direct method, but otherwise identified "filtered tailings" technology as the primary BAT. (Panel Report at 122). In doing so, the Panel suggested that "There are no overriding technical impediments to more widespread adoption of filtered tailings technology," (Panel Report at 122) and "While economic factors cannot be neglected, neither can they continue to pre-empt best technology"(Panel Report at 123).

The BC Revisions define BAT as "the site-specific combination of technologies and techniques that most effectively reduce the physical, geochemical, ecological and social risks associated with tailings storage during all stages of operation and closure" (Mines Act, RSBC 1996, Ch. 293 § 1 [hereafter "BC Revisions"]). The BC Revisions incorporate a "combination of technologies" to "reduce" risk during all stages of the TSF life-cycle. The BC revisions do not include or identify the BAT principles identified by the Panel, or filtered tailings as the prime BAT with cost as a secondary factor. The BC Revisions are not consistent with the Panel recommendations. They do not provide the underlying BAT principles or identify BAT technology to "prevent" or achieve zero risk of TSF failures, but instead the approach uses site specific technologies and techniques to "reduce" the risk of TSF failures.

It is important to note that subsequent to the Panel report, BC regulators had engaged in additional discussions with Dirk van Zyl, one of the three Panel members, who has issued a letter suggesting he favors the approach being taken by BC regulators consistent with industry recommendations. In response, Steve Vick, another Panel member, has provided comments suggesting that the Panel recommendations were to achieve zero risk by the use of primary BAT and that any compromise will result in further avoidable TSF failures. Those communications are attached as Appendix A to these comments in the interest of ensuring that the views of the IERP and Dr. van Zyl are available for consideration by the public and the regulators that may otherwise depend on them to be representative of the IERPs views. [1]

The MT MMRA Revision requires "an evaluation indicating that the proposed tailings storage facility will be designed, operated, monitored, and closed using the most applicable, appropriate, and current technologies and techniques practicable given site-specific conditions and concerns" and defines "practicable" as "available and capable of being implemented after taking into consideration cost, existing technology, and logistics in light of overall project purposes" (Montana Metal Mine Reclamation Act Section 82-4 Revisions at 82-4-305(5)(2)(e), 82-4-303(25), S. 409, 64th Leg. (Mont. 2015) [hereafter "MT MMRA Revisions"]). The MT MMRA Revisions do not include or identify the BAT principles identified by the Panel, or filtered tailings as the prime BAT. The MT MMRA Revisions do not appear to be consistent with the Panel recommendations in that they do not provide the underlying BAT principles or identify BAT technology to "prevent" or achieve zero risk of TSF failures, but instead present the approach favored by industry which is to use site specific technologies and techniques to "reduce" the risk of TSF failures.

Alaska's regulations, typical to most if not all other U.S. State regulations with the exception of Montana's recent revisions, do not address either BAP or BAT or the need to evaluate them to either reduce or prevent risk of catastrophic failures. The 2017 Alaska Dam Safety Program (ADSP) New Draft Revision Guidelines for Cooperation do suggest that BATs and BMPs "should be utilized" as much as practicable, but BATs and BMPs are not required. (DAM SAFETY AND CONSTRUCTION UNIT, ALASKA DEPARTMENT OF NATURAL RESOURCES, GUIDELINES FOR COOPERATION WITH THE ALASKA DAM SAFETY PROGRAM (2017) [hereafter "Alaska regulations"]).

b. Improve corporate governance

[1] Communications can be provided

The Panel recommended that corporations operating TSFs should be required to be a member of the Mining Association of Canada (MAC) or be obliged to commit to an equivalent program for tailings management, including the audit function.

The MAC, in response to issues presented by TSFs worldwide owned by Canadian based corporations, developed guidelines for tailings management that are considered worldwide as best management practice (BMP). These BMP guidelines include: "A Guide to the Management of Tailings Facilities;" "Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities;" and "A Guide to the Audit and Assessment of Tailings Facility Management."[2] The Tailings Management Protocol was updated in 2011, 2017, and 2019, in part implementing Panel recommendations for corporate governance.

The BC Revisions fall short of the Panel recommendations in that while they require the mine manager to "consider" the HSRC Guidance Document, it does not require they be a member of MAC or be obliged to commit to an equivalent program.

The MT MMRA Revisions require a description of proposed risk management measures. They fall far short of the Panel recommendation and require no obligation to a program equivalent to those required of MAC members. There are no equivalent U.S. based industry or professional groups that have developed equivalent tailings management guidance or that similarly oblige their members to commit to an equivalent program.

The Alaska regulations, typical to most if not all other U.S. State regulations including Montana's recent revisions, do not address or provide stringent and current requirements for tailings management similar to those contained in MAC guidance and member obligations.

c. Expand corporate design commitments

The Panel recommended that new TSFs "should be based on a bankable feasibility study and consider all technical, environmental, social and economic aspects of the project in sufficient detail to support an investment decision" and should contain a failure modes and effects analysis, cost/benefit analysis of BAT tailings and closure options with the caveat the

[2] *Tailings Management Protocol,* MINING ASSOCIATION OF CANADA (2019), https://mining.ca/towards-sustainable-mining/protocols-frameworks/tailings-management-protocol/.

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cost/benefit should not super-cede safety considerations, and detailed and declared Quantitative Performance Objectives (QPOs) (Panel Report at 127).

The BC Revisions are for the most part consistent with the Panel's recommendations. They require risk assessment and management, an alternatives assessment of best available technology, and QPO's. The primary difference with the Panel recommendations is that the alternatives assessment does not specifically require that safety considerations must not super-cede cost/benefit considerations.

The MT MMRA Revisions are for the most part consistent with the Panel's recommendations. They require a failure modes effects analysis, QPO's and risk management measures. The primary difference with the Panel recommendations is that the MT MMRA Revisions do not specifically require that safety considerations must not super-cede cost/benefit considerations.

The Alaska regulations do not require a failure modes effects analysis, BAT cost-benefit analysis, or QPOs, similar to most if not all other U.S. State regulations with the exception of Montana's recent revisions. Typical to water reservoirs, they do require analysis of a dam break flood as a result of dam failure. The 2017 ADSP Revised Draft Guidelines do suggest that QPOs, potential failure modes, and a risk assessment should be addressed in the design, but are not required.

d. Enhance validation of safety and regulation of all phases of a TSF

The Panel recommended that Independent Tailings Review Boards (ITRBs) be utilized together with QPOs to improve safety and regulation of all phases of TSFs.

The BC Revisions require an ITRB and the submission of the terms of reference and qualifications for board members for approval. The BC Revisions also require a report of the activities of the ITRB, confirmation and incorporation of ITRB recommendations, and assurance that the report is a true and accurate representation of their reviews. The BC Revisions do not address the use of QPOs to improve regulator evaluation of TSFs. The BC Revisions do not address the requirements for ITRB members to be independent of the proponent.

The MT MMRA Revisions require an ITRB and the submission and approval of board members. The MT MMRA Revisions do not require the submission and approval of the terms of reference for the ITRB. The MT MMRA revisions require that "[t]he panel shall review the design document, underlying analysis, and assumptions for consistency with this part. The panel shall assess the practicable application of current technology in the proposed design. (9) The panel shall submit its review and any recommended modifications to the operator or permit applicant and the department. The panel's determination is conclusive. The report must be signed by each panel member" (MT MMRA Revisions, 82-4-305(6)(8-9)). The MT MMRA Revisions do not address the use of QPOs to improve regulator evaluation of TSFs.

The Alaska regulations do not address either ITRBs or use of QPOs in regulator evaluation. The 2017 ADSP Revised Draft Guidelines do suggest QPOs and ITRBs but they are recommended and not required and additionally, the reports may be held in confidence and not made available to the public.

e. Strengthen current regulatory operations

The Panel recommended that inspections be performed at all existing TSFs to ascertain whether they may be a risk and require appropriate actions due to specific failure modes: filter adequacy; water balance adequacy; undrained shear failure of silt and clay foundations.

The BC government required inspections to be completed and submitted by June 30, 2015 to comply with the Panel's recommendations.

The Montana MMRA Revisions do not require inspections for this purpose although the requirement for both annual EOR and independent audit inspections can be construed as requiring these failure modes be addressed.

The Alaska regulations do not require inspections specific to these failure modes.

f. Improve professional practice

The Panel encouraged the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) to develop guidelines that would lead to improved site characterization for tailings dams with respect to the geological, geomorphological, hydrogeological and possibly seismotectonic characteristics.

The APEGBC developed and published professional practice guidelines in August 2016, including a section on seismotectonic conditions (ASSOCIATION OF PROFESSIONAL ENGINEERS AND GEOSCIENTISTS OF BRITISH COLUMBIA, SITE CHARACTERIZATION FOR DAM FOUNDATIONS IN BC, V1.2 (2016)).

There are no equivalent U.S. or Alaska based industry or professional groups that have developed equivalent site characterization guidance for either dams or TSFs.

g. Improve dam safety guidelines

The Panel, recognizing limitations of current Canadian Dam Association guidelines, recommended that dam safety guidance be developed specific to the conditions encountered with TSFs in British Columbia and incorporated as a statutory requirement. The Montana and BC dam safety regulations include prescriptive and specific design criteria requirements for TSFs. Alaska has developed draft guidelines for dam safety that include some prescriptive and specific design criteria requirements.

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Table 1. Comparison of Mine Tailings BADCT and Regulations
Mt Polley Expert Panel, Montana SB409 Revisions, British Columbia Part 10 HSRC Revisions, Alaska Department of Natural Resources

Mount Polley Expert Panel Recommendations (2014)	Montana Metal Mine Reclamation Act Section 82-4 Revisions 7(SB 409) (2015)	British Columbia Health, Safety and Reclamation Code Part 10 Revisions (2016)	Title 11, Chapter 93, Section 193, AAC ADSP Revised Draft Guidelines for Cooperation (2017)
Implement Best Available Technologies (BAT) using a phased approach: • Existing TSFs. Rely on best practices for the remaining active life. • New TSFs. BAT (filtered tailings) should be actively encouraged for new tailings facilities at existing and proposed mines. • At closure. BAT principles (no surface water, unsaturated conditions, achieve dilatant conditions) should be applied to closure of active impoundments so that they are progressively removed from the inventory by attrition.	**82-4-303. Definitions.** (25) "Practicable" means available and capable of being implemented after taking into consideration cost, existing technology, and logistics in light of overall project purposes. **Section 5. Tailings Storage facility - design document - fee.** (2) The design document must contain: (e) an evaluation indicating that the proposed tailings storage facility will be designed, operated, monitored, and closed using the most applicable, appropriate, and current technologies and techniques practicable given site-specific conditions and concerns;	**Definitions.** "best available technology" means the site -specific combination of technologies and techniques that most effectively reduce the physical, geochemical, ecological and social risks associated with tailings storage during all stages of operation and closure. **Application Requirements. 10.1.3** The application shall include the following unless otherwise authorized by the chief inspector: (f) an alternatives assessment for the proposed tailings storage facilities that assesses best available technology,	**Regulations:** None identified. **ADSP Guidelines Section 15.3.1 Design.** In any case, best available technology (BAT) and BMPs should be utilized and anticipated in the design as much as practicable.
Improve corporate governance: Corporations proposing to operate a TSF should be required to be a member of the Mining Association of Canada (MAC) or be obliged to commit to an equivalent program for tailings management, including the audit function.	**Section 5. Tailings Storage facility - design document - fee.** (2) The design document must contain: (x) a description of proposed *risk management measures for each facility life-cycle stage*, including construction, operation, and closure;	**Governance. 10.4.2** (1) The manager of a mine with one or more tailings storage facilities shall: (a) develop and maintain a *Tailings Management System that considers the HSRC Guidance Document and includes regular system audits*	**Regulations:** None identified. **ADSP Guidelines:** None identified.
Expand corporate design commitments: Future permit applications for a new TSF should be based on a bankable feasibility that would have considered all technical, environmental, social and economic aspects of the project in sufficient detail to support an investment decision, which might have an accuracy of +/- 10-15%. More explicitly it should contain the following: • A detailed evaluation of all potential failure modes and a management scheme for all residual risk • Detailed cost/benefit analyses of BAT tailings and closure options so that economic effects can be understood, recognizing that the results of the cost/benefit analyses should not supersede BAT safety considerations • A detailed declaration of Quantitative Performance Objectives (QPOs).	**Section 5. Tailings Storage facility - design document - fee.** (2) The design document must contain: (n) a dam breach analysis, a failure modes and effects analysis or other appropriate detailed risk assessment, and an observational method plan addressing residual risk; (t) a list of quantitative performance parameters for construction, operation, and closure of the tailings storage facility. The quantitative performance parameters may be expressed as minimums or maximums for embankment crest width, embankment slopes, beach width, operating pool volume, phreatic surface elevation in the embankment and foundation, pore pressures, or other parameters appropriate for the facility and location. (x) a description of proposed risk management measures for each facility life-cycle stage, including construction, operation, and closure;	**Application Requirements. 10.1.3** The application shall include the following unless otherwise authorized by the chief inspector: (d) a mine plan including: (vii) designs and details for tailings storage and a description of proposed quantifiable performance objectives, (e) a program for the environmental protection of land and watercourses during the construction and operational phases of the mining operation, including plans for (i) prediction, identification and management of physical, chemical, and other risks associated with tailings storage facilities and dams, (f) an alternatives assessment for the proposed tailings storage facilities that assesses best available technology,[i] **Governance. 10.4.2** (1) The manager of a mine with one or more tailings storage facilities shall: (d) review annually the tailings storage facility risk assessment to ensure that the quantifiable performance objectives and operating controls are current and manage the facility risks	**Regulations:** None identified. **ADSP Guidelines Section 9.3 Dam Failure Analysis** In addition to basic hydrology, static and seismic stability, and seepage control aspects common to the design of any dam or geotechnical structure, the following specific closure concerns should be addressed in the initial detailed design of a tailings dam or TSF: Performance requirements of the tailings dam and TSF, including "quantifiable performance objectives" (Morgenstern et al., 2015) and recommendations for the monitoring necessary to measure and compare actual performance to engineering requirements; Potential failure modes of the dam and tailings storage system in the final configuration, including a risk assessment;

Table 1. Comparison of Mine Tailings BADCT and Regulations (continued)
Mt Polley Expert Panel, Montana SB409 Revisions, British Columbia Part 10 HSRC Revisions, New Mexico Office of State Engineer

Mount Polley Expert Panel Recommendations (2014)	Montana Metal Mine Reclamation Act Section 82-4 Revisions (SB 409) (2015)	British Columbia Health, Safety and Reclamation Code Part 10 Revisions (2016)	Title 11, Chapter 93, Section 193, AAC ADSP Revised Draft Guidelines for Cooperation (2017)
Enhance validation of safety and regulation of all phases of a TSF: • Increase utilization of Independent Tailings Review Boards. • Utilize the concept of Quantitative Performance Objectives (QPOs) to improve regulator evaluation of ongoing facilities.	**Section 6. Independent review panel - selection - duties.** (1) An independent review panel shall review the design document required by [section 5]. (2) The operator or permit applicant shall select three independent review engineers to serve on the panel and shall submit those names to the department. The department may reject any proposed panelists. If the department rejects a proposed panelist, the operator or permit applicant shall continue to select independent review engineers as panelists until three panelists are approved by the department. (3) An independent review engineer may not be an employee of: (a) an operator or permit applicant; or (b) the design consultant, the engineer of record, or the constructor. (4) The operator or permit applicant shall contract with panel members, process invoices, and pay costs. (5) A representative of the department and a representative of the operator or permit applicant may participate on the panel, but they are not members of the panel and their participation is nonbinding on the review. (6) The engineer of record is not a member of the panel but shall participate in the panel review. (7) The operator or permit applicant shall provide each panel member with a hard copy and an electronic copy of the design document and other information requested by the panel. (8) The panel shall review the design document, underlying analysis, and assumptions for consistency with this part. The panel shall assess the practicable application of current technology in the proposed design. (9) The panel shall submit its review and any recommended modifications to the operator or permit applicant and the department. The panel's determination is conclusive. The report must be signed by each panel member. (10) The engineer of record shall modify the design document to address the recommendations of the panel and shall certify the completed design document. The operator or permit applicant shall submit the final design document to the department pursuant to [section 5]. (11) For an expansion of a tailings storage facility for which the original design document was approved by the department, the operator shall make a reasonable effort to retain the previous panel members. To replace a panel member, the process in subsection (2) must be followed.	**Governance. 10.4.2** (1) The manager of a mine with one or more tailings storage facilities shall: (c) establish an Independent Tailings Review Board, unless exempted by the chief inspector, (2) The composition of an Independent Tailings Review Board established under subsection (1) (c) shall be commensurate with the complexity of the tailings storage facility in consideration of the HSRC Guidance Document. (d) review annually the tailings storage facility risk assessment to ensure that the quantifiable performance objectives and operating controls are current and manage the facility risks, (3) The manager shall submit the terms of reference for the Independent Tailings Review Board including the qualifications of the board members to the chief inspector for approval. (4) The terms of reference for the Independent Tailings Review Board shall be developed or updated as required in consideration of the review under subsection (1) (d). **Annual Reporting. 10.4.4** The owner, agent or manager shall submit one or more annual reports in a summary form specified by the chief inspector or by the conditions of the permit by March 31 of the following year on the following: (c) a report of the activities of the Independent Tailings Review Board established under section 10.4.2 (1) (c) of this code that describes the following: (i) a summary of the reviews conducted that year, including the number of meetings and attendees; (ii) whether the work reviewed that year meets the Board's expectations of reasonably good practice; (iii) any conditions that compromise tailings storage facility integrity or occurrences of non-compliance with recommendations from the engineer of record; (iv) signed acknowledgement by the members of the Board, confirming that the report is a true and accurate representation of their reviews	**Regulations:** None identified. **ADSP Guidelines Section 15.1.3 Independent Engineering Review Board** ADNR Dam Safety recommends that the technical services team manager retain and maintain an independent engineering review board to review the design and operation of tailings dams and TSFs at a mine. An independent engineering review board should consist of highly qualified engineering experts, typically with 30 years of experience or more. However, for a mine project with a long operating life, the board should include a young, qualified engineer to provide continuity to the board over a longer period. The board should meet regularly, with more frequent intervals during the design stages, and should prepare a written report for each meeting. The reports should be submitted to ADNR Dam Safety within 30 days after each meeting. The dam owner may request that ADNR hold the board reports in confidence under the provisions of AS 38.05.035(a)(8)(C). Requests for confidentiality privileges must include that specific statutory citation.

Table 1. Comparison of Mine Tailings BADCT and Regulations (continued)

Mt Polley Expert Panel, Montana SB409 Revisions, British Columbia Part 10 HSRC Revisions, New Mexico Office of State Engineer

Mount Polley Expert Panel Recommendations (2014)	Montana Metal Mine Reclamation Act Section 82-4 Revisions (SB 409) (2015)	British Columbia Health, Safety and Reclamation Code Part 10 Revisions (2016)	Title 11, Chapter 93, Section 193, AAC ADSP Revised Draft Guidelines for Cooperation (2017)
Strengthen current regulatory operations: Utilize the recent inspections of TSFs in the province to ascertain whether they may be at risk due to the following potential failure modes and take appropriate actions: • Filter adequacy • Water balance adequacy • Undrained shear failure of silt and clay foundations	*No additional requirements for existing TSFs.*	Inspections required and completed. Final submissions received June 30, 2015. More information available at: http://www2.gov.bc.ca/gov/content/industry/mineralexploration-mining/dam-safety-inspections-2014	*No additional requirements for existing TSFs.*
Improve professional practice: Encourage the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) to develop guidelines that would lead to improved site characterization for tailings dams with respect to the geological, geomorphological, hydrogeological and possibly seismotectonic characteristics.	*No equivalent action has yet been performed by a professional organization located in the U.S.*	APEGBC developed and published Site Characterization for Dam Foundations in BC, August 2016. https://www.apeg.bc.ca/getmedia/34e1bb3f-cd39-450d-800e-614ac3850bc5/APEG_2016_Site-Characterization-for-Dam-Foundations_WEB_2.pdf.aspx	*No equivalent action has yet been performed by a professional organization located in the U.S.*

Table 1. Comparison of Mine Tailings BADCT and Regulations (continued)

Mt Polley Expert Panel, Montana SB409 Revisions, British Columbia Part 10 HSRC Revisions, New Mexico Office of State Engineer

Mount Polley Expert Panel Recommendations (2014)	Montana Metal Mine Reclamation Act Section 82-4 Revisions (SB 409) (2015)	British Columbia Health, Safety and Reclamation Code Part 10 Revisions (2016)	Title 11, Chapter 93, Section 193, AAC ADSP Revised Draft Guidelines for Cooperation (2017)
Improve dam safety guidelines: Recognizing the limitations of the current Canadian Dam Association (CDA) guidelines incorporated as a statutory requirement, develop improved guidelines that are tailored to the conditions encountered with TSFs in British Columbia and that emphasize protecting public safety.	**Section 5. Tailings Storage facility - design document - fee.** (g) a demonstration through site investigation, laboratory testing, geotechnical analyses, and other appropriate means that the tailings, embankment, and foundation materials controlling slope stability are not susceptible to liquefaction or to significant strain-weakening under the anticipated static or cyclic loading conditions, to the extent that the amount of estimated deformation under the loading conditions would result in loss of containment; (h) for a new tailings storage facility, design factors of safety against slope instability not less than: (i) 1.5 for static loading under normal operating conditions, with appropriate use of undrained shear strength analysis for saturated, contractive materials; (ii) 1.3 for static loading under construction conditions if the independent review panel created pursuant to [section 6] agrees that site-specific conditions justify the reduced factor of safety and that the extent and duration of the reduced factor of safety are acceptable; and (iii) 1.2 for postearthquake, static loading conditions with appropriate use of undrained analysis and selection of shear strength parameters. Under these conditions, a postearthquake factor of safety less than 1.2 but greater than 1.0 may be accepted if the amount of estimated deformation does not result in loss of containment. (i) for a new tailings storage facility, an analysis showing that the seismic response of the tailings storage facility does not result in the uncontrolled release of impounded materials or other undesirable consequences when subject to the ground motion associated with the 1-in-10,000-year event, or the maximum credible earthquake, whichever is larger. Any numeric analysis of the seismic response must be calculated for the normal maximum loading condition with steady-state seepage. The analysis must include, without limitation, consideration of: (i) anticipated ground motion frequency content; (ii) fundamental period and dynamic response; (iii) potential liquefaction; (iv) loss of material strength; (v) settlement; (vi) ground displacement; (vii) deformation; and (viii) the potential for secondary failure modes.	**10.1.8** (1) Seismic and flood design criteria for tailings storage facilities and dams shall be determined by the engineer of record based on the consequence classification determined under section 10.1.7 of this code in consideration of the HSRC Guidance Document, subject to the following criteria: (a) for tailings storage facilities that store water or saturated tailings, (i) the minimum seismic design criteria shall be a return period of 1 in 2475 years, (ii) the minimum flood design criteria shall be a return period1/3rd of the way between the 1 in 975-year event and the probable maximum flood, and (iii) a facility that stores the inflow design flood shall use a minimum design event duration of 72 hours; (b) for tailings storage facilities that cannot retain water or saturated tailings, (i) the minimum seismic design criteria shall be a return period of 1 in 975 years, and (ii) the water management design shall include an assessment of tailings facility erosion and surface water diversions as well as measures to prevent impounded tailings from becoming saturated that consider the consequence classification as determined under section 10.1.7 of this code. (2) The environmental design flood criteria shall be determined by a Professional Engineer in consultation with other qualified professionals. **10.1.9** For a tailings storage facility design that has an overall downstream slope steeper than 2H:1V, the manager shall submit justification by the engineer of record for the selected design slope and receive authorization by the chief inspector prior to construction. **10.1.10** For a tailings storage facility design that has a calculated static factor of safety of less than 1.5, the manager shall submit justification by the engineer of record for the selected factor of safety and receive authorization by the chief inspector prior to construction.	**6.4 Seismicity** 11 AAC 93.171(f)(1(F) indicates that seismic parameters for the location of the dam, including peak ground acceleration, the maximum credible earthquake, the maximum design earthquake, and the operating basis earthquake must be determined in substantial accordance with the USACE Earthquake Design and Evaluation for Civil Works Projects (2016) or other methods approved by Dam Safety if described in the design scope proposal. (See Section 5.1.7.) Additional guidance is provided in the following reference: θ Federal Guidelines for Dam Safety: Earthquake Analyses and Design of Dams (FEMA, 2005a) Table 6-2. Operating- and Safety-Level Seismic Hazard Risk Dam Hazard Classification Return Period, Years Operating Basis Earthquake Maximum Design Earthquake I 150 to >250 2,500 to MCE II 70 to 200 1,000 to 2,500 III 50 to 150 500 to 1,000

	(j) if a pseudo-static stability analysis is performed to support the design, a justification for the use of the method with respect to the anticipated response to cyclic loading of the tailings facility structure and constituent materials. The calculations must be accompanied by a description of the assumptions used in deriving the seismic coefficient.		

[i] BC HSRC for Mines Version 1.0, July 2016. The alternatives assessment for TSFs will consider BAT and will provide a comparative analysis of options considering the following sustainability factors: Environment; Society; Economics.

Appendix 4B

FMEA Risk Rating Tools

Table 1. Consequences Severity Matrix

	Severity Descriptors				
Consequence Categories	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
1. Environmental Impact	No impact.	Minor localized or short-term impacts.	Significant impact on valued ecosystem component.	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.	Serious long-term impairment of ecosystem function.
2. Traditional Use	Some disturbance but no impact to traditional land use.	Minor or perceived impact to traditional land use.	Some mitigable impact to traditional land use.	Significant temporary impact to traditional land use.	Significant permanent impact on traditional land use.
3. Regulatory and Legal	Informal advice from a regulatory agency.	Technical/Administrative non-compliance with permit, approval or regulatory requirement. Warning letter issued.	Breach of regulations, permits, or approvals (e.g. 1 day violation of discharge limits). Order or direction issued.	Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits). Prosecution.	Major breach of regulation – willful violation. Court order issued.
4. Consequence Costs	<$100,000	$100,000 - $500,000	$ 500,000 - $2.5 Million	$2.5 - $10 Million	>$10 Million
5. Community/ Media/ Reputation	Local concerns, but no local complaints or adverse press coverage.	Public concern restricted to local complaints or local adverse press coverage.	Heightened concern by local community, criticism by NGOs or adverse local /regional media attention.	Significant adverse national public, NGO or media attention.	Serious public outcry/demonstrations or adverse International NGO attention or media coverage.
6. Human Health and Safety	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability/impairment and /or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Severe irreversible disability or impairment to one or more people.	Single fatality or multiple fatalities.

Table 2. Likelihood Terminology

Likelihood	Frequency Descriptor 1	Frequency Descriptor 2
Almost Certain	Happens often	High frequency (more than once every 5 years)
Likely	Could easily happen	Event does occur, has a history, once every 15 years
Possible	Could happen and has happened elsewhere	Occurs once every 40 years
Unlikely	Hasn't happened yet but could	Occurs once every 200 years
Very Unlikely	Conceivable, but only in extreme circumstances	Occurs once every 1000 years

Table 3. Risk Matrix

Likelihood	Consequence Severity				
	Very Low	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain	Moderate	Moderately High	High	Very High	Very High
Likely	Moderate	Moderate	Moderately High	High	Very High
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High